Department
OF
Geology and Forestry
OF
Kentucky

CONTRIBUTIONS TO KENTUCKY GEOLOGY

DEPARTMENT
OF
GEOLOGY AND FORESTRY
OF
KENTUCKY

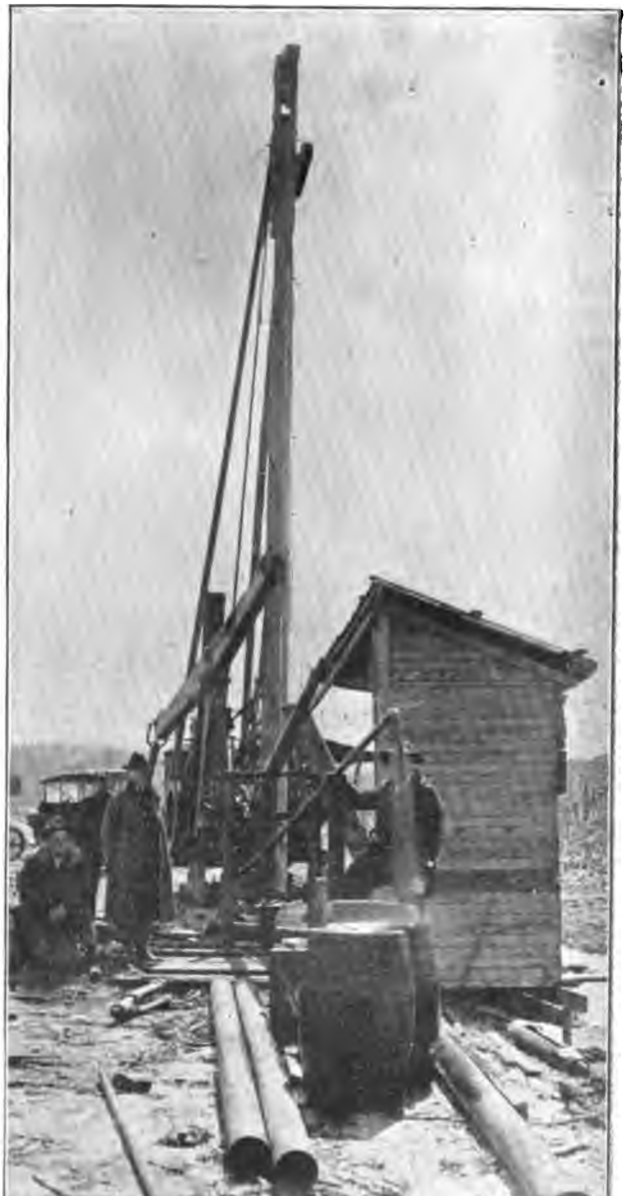
SERIES FIVE, BULLETIN FOUR

J. E. BARTON,
Commissioner

W. R. JILLSON,
State Geologist

THE STATE JOURNAL COMPANY
Printer to the Commonwealth
Frankfort, Kentucky.

To
My most helpful advisor
and faithful companion
ORIOLE GORMLEY JILLSON



STEFFY POOL WELL FLOWING NATURAL.

The J. R. Winlock No. 3 (flowing) well drilled in by the J. M. Karr Oil Company, March 14, 1919. Located on the northward extension of the Steffy Pool on the lower road to Bowling Green, three and one-half miles southwest of Glasgow, Barren County, Ky. This well flowed light green oil 44.6 Baume during an half-hour gauge by the writer, one barrel every five minutes. The well made considerable gas, but no water. Photo by W. R. Jillson, March 31, 1919. (See paper No. VIII.)

CONTRIBUTIONS TO
KENTUCKY GEOLOGY

An Indexed Collection of All the Shorter Papers and Reports of the State Geologist Written During the Year 1919 on the Mineral Resources of the Commonwealth

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BY

WILLARD ROUSE JILLSON

Kentucky State Ceologist

ILLUSTRATED WITH SIXTY-FIVE PHOTOGRAPHS, MAPS, AND DIAGRAMS

FIRST EDITION

Department of Geology and Forestry

FRANKFORT, KY.

1920

PREFACE

THE development of the mineral resources of the State of Kentucky, and the expansion of the allied industries has been tremendous during the last year. The total production of crude oil for the whole State, in 1918, was 4,308,893 barrels, valued at $11,128,421.00. In 1919, the total amount of crude oil produced was 9,226,473 barrels, which sold for $24,459,017. The tonnage figures of coal mined in Kentucky have also shot ahead, increasing from 27,809,976 tons valued at $60,297,653.00 in 1917, to 31,530,442 tons valued at $94,591,326 in 1918. Figures covering the various other tonnage values of mineral production in 1919 are not yet available, but are known to have expanded in similar proportions.

This unprecedented growth has resulted in a corresponding demand for detailed geological information concerning the mineral resources of this State. To meet this demand the State Geologist has during the year, made a large number of field examinations, results of which have been embodied in several short reports, which have been printed in pamphlet form in the Mineral and Forest Resource series. These paper bound books were issued in small editions, ranging from 750 to 2,500 copies. They were almost immediately exhausted in edition, and the daily and insistent demand for them since their exhaustion, has clearly indicated the pressing need for their reprint. These papers are therefore, brought together here under a single title for the convenience of the interested public. No changes have been made in the separate reports other than those required in resetting of the type, or to correct evident errata of one kind or another. This edition bound in linen is limited to 2,000. Single copies may be secured by remitting 20 cents in stamps to this office, to cover postage, etc.

W. R. Jillson

State Geologist of Kentucky.

Old Capitol.
Frankfort, Ky.
March 1, 1920.

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Sketch of the Development of the Oil and Gas Industry In Kentucky During the Past Century (1819-1919).

As might be expected, Kentucky forming the southwestern portion of the Appalachian oil field, has a history of oil and gas development which is in many respects parallel to that of the earlier developed portions of this extensive region, including parts of the states of Pennsylvania, New York, West Virginia and Ohio. Petroleum, commonly called "Crude Oil," was first discovered by accident in Kentucky in 1819,* in the valley of the South Fork of the Cumberland River, close to the Tennessee line. This original oil bearing area is now in McCreary County, but was at that time a part of Wayne County.

The strike, lucky as it may now be considered in the light of subsequent events, was not then so regarded for the drilling prospector, Martin Beatty, of Abingdon, Virginia, was drilling in the search of salt brine for the purpose of making domestic, evaporated salt. Needless to say the oil, which was thick and heavy, flowing slowly according to report, ruined the chances of salt recovery from that particular well. The surface rocks at the location of this first well were included within the Mississippian system and it is probable that the production came from the same rocks, as the well was only a few hundred feet deep. Regarded at this early time as of no particular value, hundreds of barrels of this first Kentucky crude oil were allowed to waste down the waters of the creek, only a very small portion of it being used by the farmers of the locality to besmear their swine in an effort to rid them of vermin.

Cumberland County, about forty miles further to the west and therefore samewhat higher up on the saddle of the Cincinnati Arch, followed with flowing production from the Upper Ordovician rocks in 1829† This well, which was only 175 feet deep, was drilled in on Renocx Creek. It soon became famous, coming to be known as the "Burkesville well," due to the fact

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* Annual report of Inspector of Mines of Kentucky for 1896, p. 294.

†Report on occurrence of Petroleum, Natural Gas, and Asphalt Rock in Western Kentucky—Orten—Ky. Geol. Surv. 1891. P. 144.

that the oil caught fire at a distance about forty miles down the Cumberland River and burned back to the source at the well. The sight must indeed have been a strange one to the then inhabitants of the valley, who were so thoroughly unaccustomed to "the new rock oil" and its inflammable qualities. This well continued to flow for several weeks, after which it was bailed out by farmers until the time of the Civil War. The greatest practical good attributed to it at this period was medicinal, and for this purpose it was recovered and bottled and sold for many years. The production came from a porous strata of the Cincinnatian and may be considered as of only local significance, as a large amount of drilling into this series of limestone in other portions of Kentucky has found it to be without commercial possibilities.

A few years following the oil strike in Cumberland County petroleum was discovered in the Lower Coal Measures of Knox County, near Barbourville. This well, a shallow one, flowed for a short time. It was found by salt brine prospectors. With its discovery the vertical geological delimitations of the future producing "sands" of the state of Kentucky were established since subsequent prospecting has shown no commercial production either higher or lower in the geological scale, though it is true that much has been found in beteween the limits that was not known at this early time.

Kentucky A National Oil Producer.

The temporary halt in the development of the oil and gas fields occasioned by the Civil War was suddenly brought to a close by a wave of excitement in prospecting which spread over Kentucky during the latter part of the sixties. Wells were drilled in all parts of the state. Allen, Barren and Clinton and many other counties joined the list of the commercial producers. During the latter part of the nineteenth century a growing demand for crude oil for kerosene-refining as well as a growing list of by-products restimulated field activity and resulted in the bringing in of reports of production or oil shows in practically every county in the state, outside of the central "Bluegrass" region. Floyd, Knox and Wayne Counties came to the front with substantial though small new oil production from the deeper

sands of the Pennsylvanian and Mississippian systems. Martin, Meade and Breckinridge counties at the same time developed gas, the production coming from the "Big Lime" and the "Big Injun" of the Mississippian System in Martin County; the "Black Shale" of the Devonian System of Meade County; and the "Warsaw" of the Mississippian System in Breckinridge County. Martin County gas in volume flowing production climbed to 35,000,000 cubic feet daily by the beginning of the new century and did not reach its peak daily production until several years later when it reached nearly one hundred million. The shallow fields of Meade and Breckinridge soon attained their maximum production of about ten to twelve million cubic feet and went into the decline.

Oil Pools Discovered Since 1900.

The Ragland Pool.

In 1900 the Ragland Oil Pool in Bath, Rowan and Menifee counties, producing a black, thick, low gravity oil was first drilled in. The production of this field as originally defined and now nearly exhausted, came from the "Corniferous" or Onondaga limestone—the "Irvine Sand" of drillers—at the base of the Devonian System. In this field the oil "pay" was found at various depths of from 200 to 900 feet below the surface.

The Menifee Gas Field.

The now widely known Menifee gas field was drilled in the following year 1901, the gas coming from the Onondaga limestone porous streaks as in the Ragland Oil Pool to the northeast. Production was found at about 600 feet and a strictly first class gas pool was developed which, due to the heavy drain placed upon it during the last few years, is now on the decline. Only relatively very small amounts of natural gas have been taken from this field since 1912.

The Sunnybrook Pool.

The Sunnybrook Pool of Wayne County was opened in 1901, oil coming at a depth of 870 feet from the "Stray," "Mt. Pisgah," "Beaver," "Otter," "Cooper." and "Slickford" sands of the Mississippian System. Later the Lower Sunnybrook "sand" from the Trenton of the Ordovician Sys-

"LOOSENING THE SAND WITH A SHOT."

Remarkable view in the Ragland Oil Pool showing expulsion of associated oil, water, rock fragments and sand. Photo by R. L. McClure.

tem was found to be an oil producer in this locality. Renewed deeper drilling in all the old fields above noted continued with varying success.

Oil Pipe Line Development in Kentucky.

The greater part of the oil of this early period was transported to the eastern markets by the Kentucky Oil Pipe Line Company. This corporation was the first large operating oil pipe line company in Kentucky. In 1900 the Kentucky Oil and Pipe Line Company was purchased by new capitalistic interests, and run until 1901 as the National Transit Company, Kentucky and Tennessee division. At this time another change was made and since 1901 these collecting and transporting oil lines within the state of Kentucky have been owned and operated by the Cumberland Pipe Line Company. The main trunk line of the Cumberland Pipe Line Company connects with that of the Eureka Pipe Line Co., at Morgantown, W. Va., which line connects with the Southern Pipe Line Co., delivering practically all of the Kentucky Somerset grade at Philadelphia, Pa.

The collecting and trunk lines of the Cumberland Pipe Line are now connected with every oil pool of commercial importance in Eastern and Southeastern Kentucky. However, although this company has put forth every effort to handle the production of its field, going so far as to install within the last two years duplicate or loop lines, new gravity collecting systems, and additional pumping stations, the great increase in production in Eastern Kentucky, especially in Estill, Lee and Powell counties, has steadily kept ahead of the facilities of pipe line transportation. It is certain that today in this section there is from one to two thousand barrels of semi-isolated daily production that is "closed in" or in tankage awaiting a means of outlet.

Recent and Present Oil Pool Discoveries.

The Campton Pool.

In 1903 the Campton Oil Pool of Wolfe County was discovered, oil being found again in the Onondaga limestone—the "Irvine Sand" of drillers—at the base of the Devonian System. The wells averaged from 1,000 to 1,200 feet in depth. About

SNAGGED ON THE ROAD

The job of getting the rig onto the locations is often a tough one, as this view on the road from Torrent, Wolfe County, shows.
Photo by Author, 1918

300 were drilled into this small field, averaging in production about fifty barrels each. At the time of the Campton activity a small amount of oil production was secured by wildcatters near Irvine, in Estill County. Due, however, to the extreme shallowness of the Onondaga limestone here, this area was soon drilled up and exhausted.

The Bussyville and Fallsburg Pools.

The Bussyville and Fallsburg Pools of Lawrence County were opened in 1903, the oil coming from the Berea "Grit" or sandstone at a depth of from 1,400 to 1,600 feet. This production per well has never been very large but has, like all of the deeper production in Eastern Kentucky, presented the very distinct advantage of dependability and long life. Within the last three or four years the production of this section has been increased from about 1,800 barrels per month in 1915 to the present production of nearly 6,000 barrels per month. This increase has been largely accomplished by the extension of the known producing areas and the discovery of small adjacent pools by wildcatting.

The Cannel City Pool.

A few years later, in 1912, the Cannel City Oil Pool in Morgan County, was discovered. This pool started in with flowing wells of several hundred barrels, one or two being reported at 700 barrels. Great activity followed and this small field produced its maximum of 12,000 barrels of crude oil per month, in 1913. This production came from the porous streak in the Onondaga limestone and, though productive in large quantity at the time, was relatively short lived commercially.

The Irvine Pool Extension.

Due to the stalemated and over produced condition of the oil market in 1913, 1914 and 1915, field activity in Kentucky slumped very greatly and with it the oil production. With the renewed wartime demands for crude oil, however, and an increase in prices of all grades generally, a restimulation of exploration was effected which resulted in 1916 in extending the Irvine Pool, in Etill County, to the east and south.

Portable Drilling Rig being moved to location by six yoke of oxen in Western Wolfe County—Irvine Pool Extension. Photo by Author, 1918.

Storage tanks and connection of Indian Refining Company, on the E. R. Riggs Oil Company's lease New Gainesville Pool, Allen County Ky. Photo by author, Mar. 19, 1919.

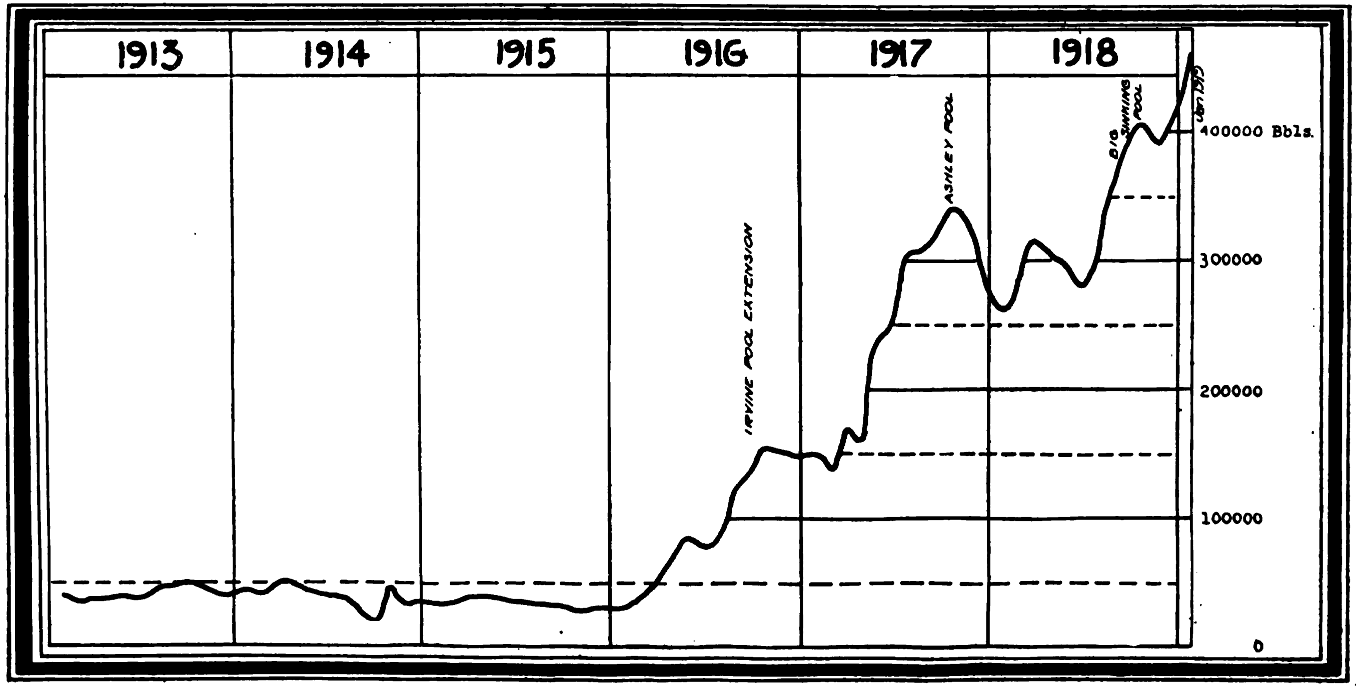
Producing Well No. 3 and Tank. Phelps and Hoge lessors on the Guy farm on Big Trammel Creek, one-half mile northwest of Butlersville, Allen County, Ky. Photo by author, March 18, 1919.

The Ashley, Big Sinking and Gainesville Pools.

In Powell County the Ashley Oil Pool was opened in 1917, in Lee County the Big Sinking Oil Pool in 1918, and in Allen County the new Gainesville Pool of 1918 and 1919, representing today the centers of greatest activity and production in Kentucky. The Ashley and Big Sinking Pools found their production in the Onondaga limestone as did the other productive pools of this portion of the state. The Gainesville oil production comes from a similar porous limestone lying in the same position as the Onondaga—that is just beneath the Black Shale—but it is impossible to say at present, for lack of definite evidence, whether this limestone is the Onondaga limestone, or some porous lime from the Niagaran group in the upper part of the Silurian System. In the Ashley and Big Sinking fields of Estill, Powell, Lee and Wolfe counties of Eastern Kentucky the Onondaga "pay" or "oil." "sand" ranges from 800 to 1,300 feet below the urface. In the new Gainesville field of Allen County the production comes at a depth of from 250 to 350 feet below the surface. There are at the present between 600 and 800 rigs drilling in the state of Kentucky, and this number will be increased by a hundred or more before the season closes. The production from the Big Sinking and its associated pools and that of the Gainesville pool in total will for the years 1918 and 1919 exceed by many thousand barrels the total production of the entire state of Kentucky up to this time. Detailed figures showing actual pipe line runs will be found elsewhere in this paper.

KENTUCKY OIL PIPE LINES—PRODUCTION.

Practically all of the Eastern Kentucky production is now handled by the Cumberland Pipe Line Company whose pipe line extensions connect the producing pools of Wayne, Floyd, Estill, Lee, Wolfe, Powell, Morgan and Lawrence counties. The Ragland pool, in Bath, Menifee and Rowan counties, is connected by a small pipe line with a tank car station at Salt Lick, in Bath County, on the Chesapeake and Ohio Railroad. In Allen County the new Gainesville pool has two short pipe line connections, one two-inch line to Bowling Green, and one four-inch line to Scottsville. The line to Bowling Green is owned by the American Pipe Line Company, and the one to Scottsville by the



CURVES OF PETROLEUM PRODUCTION IN THE EASTERN KENTUCKY FIELDS, SHOWING TOTAL PIPE LINE RUNS BY MONTHS, FROM 1913-1918.

Note:—This plate was prepared by the author from data furnished by Mr. Oscar Wolf, of the Cumberland Pipe Line Co. It underestimates slightly the total production of this part of Kentucky, since a small amount of the production is handled by other agencies.

Indian Refining Company. Both of these lines end at tank car stations. Practically all of the production in Lincoln County is handled by the Daniel Boone Oil Company Pipe Line. The line, which is rather short, ends at a tank car station, and product goes to Louisville. The following production tables are given:

PRODUCTION OF PETROLEUM IN BARRELS IN KENTUCKY FROM 1883 TO 1919.

1883	4,755
1884	4,148
1885	5,164
1886	4,726
1887	4,791
1888	5,096
1889	5,096
1890	6,000
1891	9,000
1892	6,500
1893	3,000
1894	1,500
1895	1,500
1896	1,680
1897	322
1898	5,568
1899	18,280
1900	62,259
1901	137,259
1902	185,331
1903	554,286
1904	998,284
1905	1,217,337
1906	1,213,548
1907	820,844
1908	727,767
1909	639,016
1910	468,774
1911	472,458
1912	484,368
1913	522,550
1914	479,609
1915	407,081
1916	1,144,750
1917	3,015,640
1918	4,035,950
1919	9,226,473

CRUDE PETROLEUM PRODUCTION IN EASTERN KENTUCKY FOR THE YEARS 1916-1917-1918
MONTHLY RUNS BY DISTRICTS—CUMBERLAND PIPE LINE COMPANY

YEAR	MONTH	Wayne Co.	Lawrence County	Morgan	Cow Creek and Fitchburg	Campton Stillwater	Beaver Creek	Ragland	Wagersville	Ashley	Torrent and Lee Co.	Ross Creek	Olympia
1916	January	17,899	1,829	1,683	2,410	2,384	948	3,646					
	February	17,040	2,510	2,794	9,627	2,906	904	2,564					
	March	17,758	3,333	1,908	19,405	2,925	838	3,075					
	April	16,574	2,577	2,083	34,650	2,911	1,079	3,231					
	May	18,220	3,347	1,662	53,769	2,220	964	3,166					
	June	16,299	3,239	1,927	48,138	3,281	853	2,732					
	July	16,156	3,383	1,732	58,769	2,190	644	3,099					
	August	16,885	3.676	2,829	95,592	2,846	782	3,180					
	September	14,535	3,190	1,677	111,795	2,692	1,908	2,071					
	October	15,774	4,434	1,840	126,310	2,489	1,330	2,970					
	November	14,433	2,886	1,605	127,732	2,805	649	2,540					
	December	13,046	4,277	1,596	120,334	2,370	664	2,685	2,244				
1917	January	14,857	3,687	1,748	118,484	3,165	849	2,320	5,220				
	February	12,179	3,926	1,365	94,254	2,117	478	3,348	15,453	3,918			
	March	15,153	4,714	1,490	104,886	2,441	761	1,914	30,376	9,620			
	April	14,850	4,462	216	94,581	3,846	599	2,990	36,367	4,904			
	May	14,205	4,385	2.746	151,290	3,768	688	2,229	33,574	13,683			
	June	13,867	4,646	1,458	180,686	3,820	897	3,037	24,936	20,762			
	July	14,979	5,389	1,607	222,267	4,484	642	2,043	14,991	42,539			
	August	14,302	5,936	1,396	204,960	3,343	567	1.917	12,550	48,333			
	September	12,645	4,871	1,230	176,948	3,217	949	1,702	10,762	83,672			
	October	14,444	5,464	1,936	205,779	3,473	480	2,211	10,514	101,762	318		
	November	13,468	5,285	1,302	201,917	2,590	424	2,175	9,591	95,523	626		
	December	11,776	4,289	1,132	138,599	2,558	530	1,539	7,520	82,088	3,908		
1918	January	11,271	4,972	1,564	150,490	2,827	589	2,070	4,741	79,760	4,141		
	February	14,470	6,322	1,235	172,991	2,911	692	1.591	6,110	74,156	4,518		
	March	13,869	6,077	1,524	191,959	2,443	458	2,136	5,663	84,747	7,877		
	April	15,396	5,924	1,934	135,409	2,470	894	1,934	3,748	87,336	11,806		
	May	15,374	6,304	1,693	152,933	2,783	831	2,160	3,959	87,467	24,518		
	June	14,197	5,905	1,562	139,528	2,717	339	1,035	2,863	74,208	37,732		
	July	15,338	6,379	1,978	132,525	3,062	533	2,373	2,471	77,983	58,434	2,982	
	August	13,533	5,508	1,260	120,293	2,859	711	1.679	1,854	68,215	129,355	15,317	
	September	13,852	5,325	1,445	116,111	2,507	359	1,874	1,982	64,753	158,294	28,017	496
	October	13,765	5,480	1,410	106,624	1.577	1,333	1,529	1,586	64,062	173,307	37,757	108
	November	12,235	5,126	1,778	88,298	2,474	791	1,137	1,812	50,717	189,907	39,375	360
	December	12,367	5,695	1,509	86,616	1,595	523	1,666	2,300	54,329	213,794	42,579	239
1919	January	13.251	6,311	1,151	73,987	1.818	609	1,324	1,201	55,055	280,356	41,427	239

PRODUCTION OF CRUDE PETROLEUM IN EASTERN KENTUCKY FIELDS FOR THE YEARS 1912-1919.

RUNS OF CUMBERLAND PIPE LINE CO.

Year	Month	Bbls.	Total Per Yr.	Average Per Day	Remarks
1912	September	38,417			
	October	37,756			
	November	39,271			
	December	40,343		1,298.2	
1913	January	41,982			
	February	36,751			
	March	39,194			
	April	38,794			
	May	42,716			
	June	39,068			
	July	48,119			
	August	49,766			
	September	52,328			Cannel City Pool,
	October	46,082			Morgan County.
	November	43,929			
	December	43,821	522,550	1,431.6	
1914	January	45,091			
	February	42,737			
	March	52,135			
	April	48,565			
	May	43.017			
	June	42,464			
	July	40,698			
	August	24,985			
	September	19,249			
	October	49,494			
	November	34,960			
	December	36,224	479,609	1,313.9	
1915	January	34,898			
	February	34,255			
	March	38,204			
	April	38,995			
	May	37,270			
	June	35,458			
	July	32,643			
	August	32,504			
	September	30,930			
	October	29,297			
	November	31,926			
	December	30,701	407,081	1,115.3	
1916	January	30,799			
	February	38,345			
	March	49,242			
	April	63,104			Cow Creek Pool,
	May	83,348			Estill County.
	June	76,469			
	July	85,973			
	August	125,799			Fitchburg District,
	September	136,659			Estill County.
	October	155,147			
	November	152,652			
	December	147,213	1,144,750	3,136.3	
1917	January	150,330			
	February	136,138			
	March	171,325			
	April	162,816			

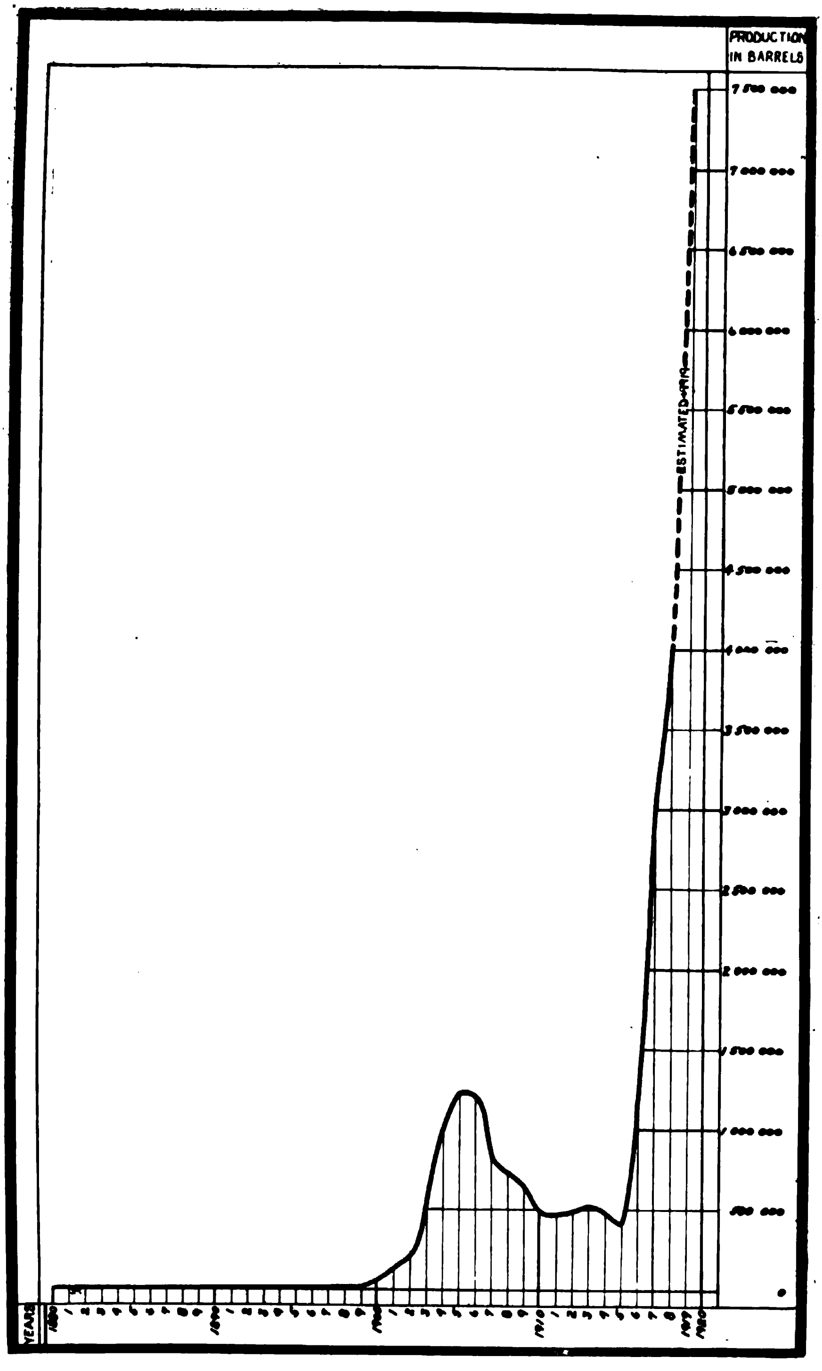
Year	Month	Bbls.	Total Per Yr.	Average Per Day	Remarks
1917	May	236,566			
	June	254,108			
	July	308,941			
	August	311,302			Ashley Pool,
	September	323,897			Powell County.
	October	346,381			
	November	332,898			
	December	280,938			
			3,015,640	8,262.0	
1918	January	262,424			
	February	285,995			
	March	316,753			
	April	306,849			
	May	298,022			
	June	280,087			
	July	304,058			Big Sinking Pool,
	August	360,586			Lee County.
	September	396,018			
	October	408,537			
	November	394,111			
	December	423,510			
			4,035,930	11,067.7	
				15,870.0	
1919	January	476,488		16,160.0	
	February				

Crude Oil Prices and Gravities.

The market price of Kentucky crude oil is now $2.60, this price covering all grades designated as "Somerset." The single exception to this general statement is that of the small Ragland production, which is designated by the same name and sells for $1.25 per barrel. The petroleum of Kentucky is for the most part light green in color, very fluid, high in gasoline content, with a gravity which runs generally between 32 and 38 Baume scale. The extremes, however, are much wider apart. The lowest of record is 22 Baume, the sample oil specimen coming from the Ragland pool in Bath County. The highest of record is 45 Baume from the Scottsville pool in Allen County.

Baume Density of Kentucky Crude Petroleum.

	Lab. No.	Degrees Baume.
1.	43475—Allen County	30.
2.	36292—Probably Bath County	24.9
3.	36293—Probably Bath County	25.4
4.	36294—Probably Bath County	24.2
5.	36295—Probably Bath County	24.5
6.	36269—Probably Bath County	24.5
7.	36270—Probably Bath County	25.0



CRUDE OIL PRODUCTION CURVE

The total petroleum production of Kentucky for the past thirty-eight years (1880-1918), is shown above. Total production for 1919 is estimated.

8.	36271—Probably Bath County	25.0
9.	36229—Probably Bath County	24.7
10.	36330—Probably Bath County	24.0
11.	36331—Probably Bath County	24.4
12.	36332—Probably Bath County	24.7
13.	36333—Probably Bath County	25.2
14.	36334—Probably Bath County	32.0
15.	36206—Probably Bath County	23.7
16.	25857—Probably Bath County	25.2
17.	14987—Morehead Oil & Gas Co.	22.5
18.	14565—"Ragland," Bath County	22.0
19.	14522—Yale Oil Company, Bath County	41.0
20.	14314—E. B. Fletcher, Powell County	22.0
21.	11964—From Bath County	22.6
22.	11190—Shouse Well, Hendrick Farm, Bath County	28 0
23.	10325—For J. B. Hoeing	35.5
24.	10241—John Williams, Lewis County	27.0
25.	10156—From Scottsville, Allen County	45.0
26.	9838—From Clinton County	41.0
27.	9749—Rose Run Iron Co., Bath County	33.0
28.	9750—From M. Carey Peter, Louisville	28.0
29.	9751—Lincoln County, near Stratford	32 0
30.	9431—From D. F. Frazee, Lexington	25.0
31.	9283—Isola Oil & Gas Co., Beech Grove, Ky.	28.0
32.	9238—Wood Richardson, Flemingsburg	38.9
33.	51656—Bowling Green, Warren County	38.9
34.	51839—Bowling Green, Warren County	38.5
35.	G-3785—Powell County	23.3
36.	G-3786—Powell County	32.8
37.	Geol. Report, 2732—Lower Laurel Creek	34.1

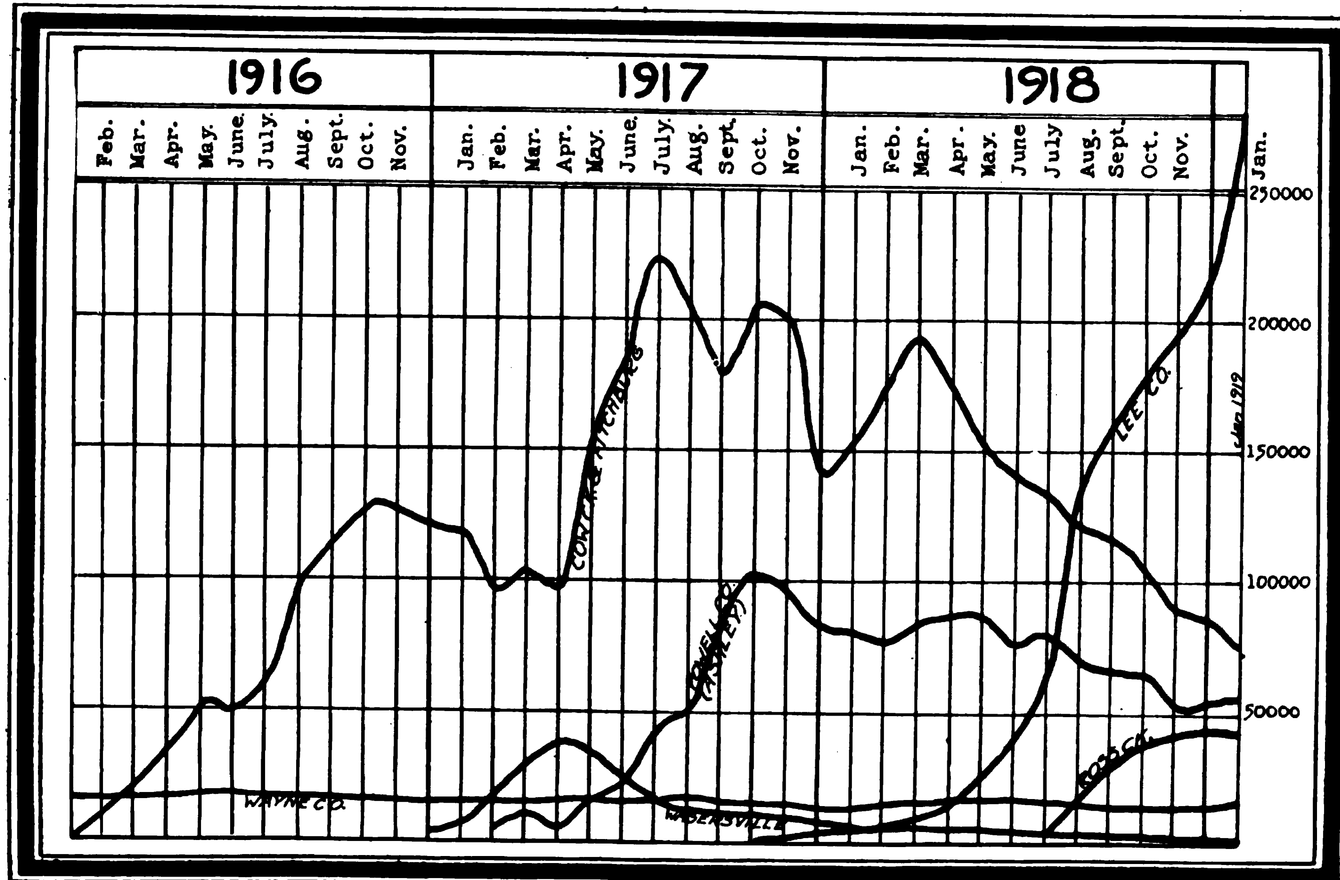
Range 22 to 45° Baume in 37 samples.

ALFRED M. PETER, Chief Chemist.

March 25, 1919.

The Kentucky Pipe Line—Gas.

The natural gas production of Kentucky is but partially commercialized for lack of extension pipe lines from the various developed gas fields to the trunk pipe lines. Crossing the state from east to west are two main trunk pipe lines. One of these, the Kentucky Pipe Line—a twelve-inch line—extends from Inez, in Martin County, to the city of Louisville, which it serves through the Louisville Gas and Electric Company. This line is



CURVES OF PETROLEUM PRODUCTION IN THE EASTEHN KENTUCKY FIELDS. DISTRICT TOTALS BY MONTHS FROM 1916-1918.

Note:—The plate herewith presented was prepared by the author from data kindly furnished by Mr. Oscar Wolf, of the Cumberland Pipe Line Co. It underestimates slightly the total production of this part of Kentucky, since a small amount of the production is handled by other agencies.

supposed to carry twelve million cubic feet of natural gas daily, but probably, as a matter of fact, carries somewhat less. The line was laid and connected in 1907 and the first gas carried by it came from both the Martin County field and West Virginia sources. However, during the last twelve years the Martin County field has shown considerable and rapid decline in both rock pressure and volume and for this reason an increasingly larger supply has come to be taken from the West Virginia compressor station at Kermit on the Tug Fork of the Big Sandy River.

THE CENTRAL KENTUCKY NATURAL GAS PIPE LINE.

The second of these large trunk gas lines, that of the Central Kentucky Natural Gas Pipe Line Company, extends from Inez, in Martin County, to Lexington and then with extension to Frankfort. This gas line has within the last eight months connected as a source of additional supply from Eastern Kentucky, the newly developed gas fields of Paint Creek in Johnson and Magoffin counties, and Laurel Creek of Johnson and Lawrence counties. The Paint Creek extension is four-inch. The Laurel Creek extension is six-inch tubing. Compressors are already working on the Laurel Creek line and will soon be in operation on the Paint Creek line. It is estimated that the Central Kentucky Natural Gas Company is now taking about between two and three million cubic feet volume of gas from these two new fields combined. This amount does not in any, except a small way, indicate what the capacity of these two gas structures will be when they are fully developed and connected to the compressor stations. Further to the west this main trunk gas line connects with the Menifee gas field where a large compressor station is located. This pipe line serves besides the larger cities of Frankfort and Lexington, the smaller cities of Mt. Sterling, Paintsville, Versailles, Midway, Winchester and Paris.

The Central Kentucky Natural Gas Pipe Line Company's line from Inez to Lexington is 10 inches. From Lexington the line is 8-inch to the Versailles "cut in" and from there on 6 inches to Frankfort. This line from Lexington to Frankfort and Versailles is owned and operated by the Frankfort Natural Gas Company. Between six and nine million cubic feet volume of gas is transported daily by the Central Kentucky Natural Gas

A UNIQUE "BLUE GRASS" DRILLING

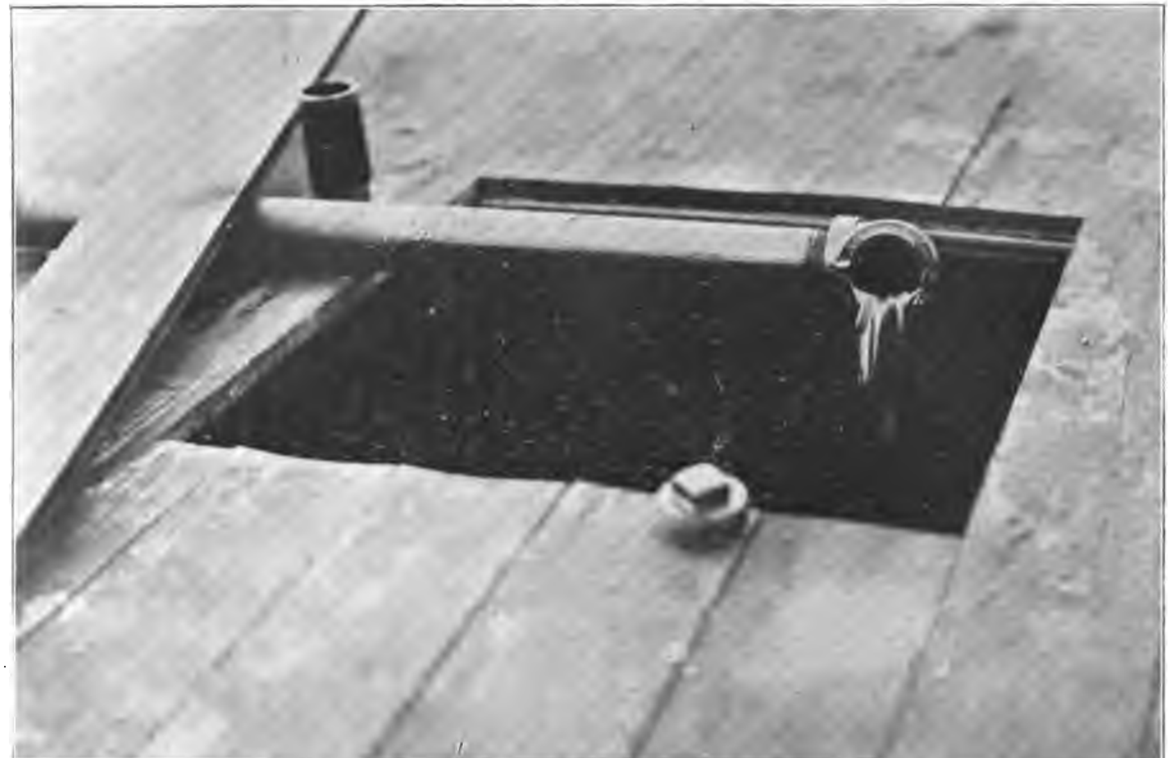
Heavy National Rig of Acker, Wilson, et al., down 1,700 feet (April 1, 1919) on William H. Hoover farm, one-quarter mile south of Nicholasville, Jessamine County. This well bears the unusual distinction of being located essentially on the highest point of the Cincinnati Arch. It was "spudded" into the Lexington limestone slightly above the Tyrone, thereby starting lower stratigraphically than any other well, and will for this reason, if drilled but a few hundred feet deeper, penetrate subsurface rocks never prospected by any other well in Kentucky. Photo by Author, March, 1919.

main trunk pipe line. Aside from the two or three million cubic feet of gas now being taken by this company from the new Paint Creek and Laurel Creek fields in Johnson, Magoffin and Lawrence counties, the greater part of the gas comes from West Virginia, through the Kermit compressor station. The Menifee field, once the principal source of supply of this pipe line, now varies from a very small contributor to simply a ready reserve supply. The Menifee to Lexington line was first installed in 1905 and was continued further eastward to Inez in 1912. The Paris extension was made in 1913 and the Frankfort extension was connected up in the fall of 1915.

VALUE OF PRODUCTION OF NATURAL GAS IN KENTUCKY FROM 1889 TO 1919.*

1889	$2,580
1890	30,000
1891	38,993
1892	43,175
1893	68,500
1894	89,200
1895	98,700
1896	99,000
1897	90,000
1898	103,133
1899	125,745
1900	286,243
1901	270,871
1902	365,611
1903	390,601
1904	322,404
1905	237,590
1906	287,501
1907	380,176
1908	424,271
1909	485,192
1910	456,293
1911	407,689
1912	522,455
1913	509,846
1914	490,875
1915	614,998
1916	752,635
1917	....
1918	....
1919	....

*Mineral Resources of United States. U. S. G. S.



Oil from Onondaga "Corniferous" Limestone of the Devonian filling storage tanks on the Jack Wells lease in the Irvine Pool Extension. Photo by R. S. McClure.

VALUE OF PETROLEUM PRODUCED IN KENTUCKY—1904 TO 1919.*

1904	$984,333
1905	943,211
1906	1,031,629
1907	862,396
1908	706,811
1909	518,299
1910	324,684
1911	328,614
1912	428,842
1913	675,748
1914	498,556
1915	418,357
1916	2,189,812
1917	....
1918	....
1919	....

KENTUCKY CRUDE OIL REFINERIES.

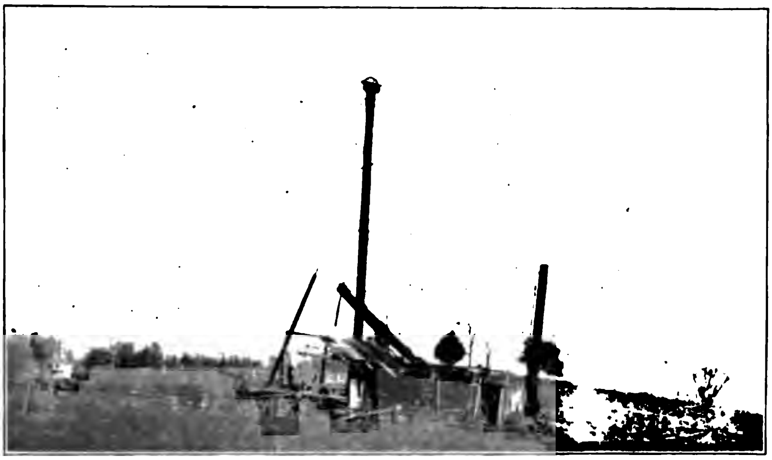
The three largest crude oil refineries in Kentucky are located at Louisville. These are the Aetna Refining Company, the Standard Oil Refining Company of Kentucky, and the Stoll Oil Company. In the Lee-Estill field there are two small refineries, the Oleum Refinery, recently burned and now being reconstructed, and the Neha Refinery. Both of these are rather small field plants. A new refinery is now being proposed, to be located at Bowling Green, and take over the production of the new Allen and Warren County production. Field refineries may and generally do pay ten cents per barrel in excess of the quoted market or ''Somerset'' price. However, the amount of crude oil handled by them is relatively very small due to the restricted capacity of their plants and collecting pipe line extensions in the fields.

GEOLOGIC AND GEOGRAPHIC DISTRIBUTION OF PETROLEUM AND NATURAL GAS IN KENTUCKY IN 1919.

In the brief space allotted to this article it is not possible to go into great detail with respect to the occurrence either geologically or geographically of oil and gas. However, the two following tables have been compiled to show concisely what is understood at present to be the distribution of these two im-

*Mineral Resources of United States, U. S. G. S.

portant hydrocarbons. The matter of geologic structural occurrence has been omitted entirely and will be taken up in a later paper. The stratigraphic section of producing sands as known in Kentucky is given first and is followed by a list of the more important oil and gas pools.



Drilling Well No. 4 by Phelps-Hoge on the Guy farm, on Big Trammel Creek, one-half mile northwest of Butlersville, Allen County, Ky. Photo by author, Mar. 18, 1919.

Producing well on the pump and Star drilling machine, both in operation on the lease operated by the E. R. Riggs Oil Company, in the new Gainesville Pool, Allen County, Ky. Photo by author, March 18, 1919.

Local Name Key to Oil and Gas Pool and Pipe Line Map

County.

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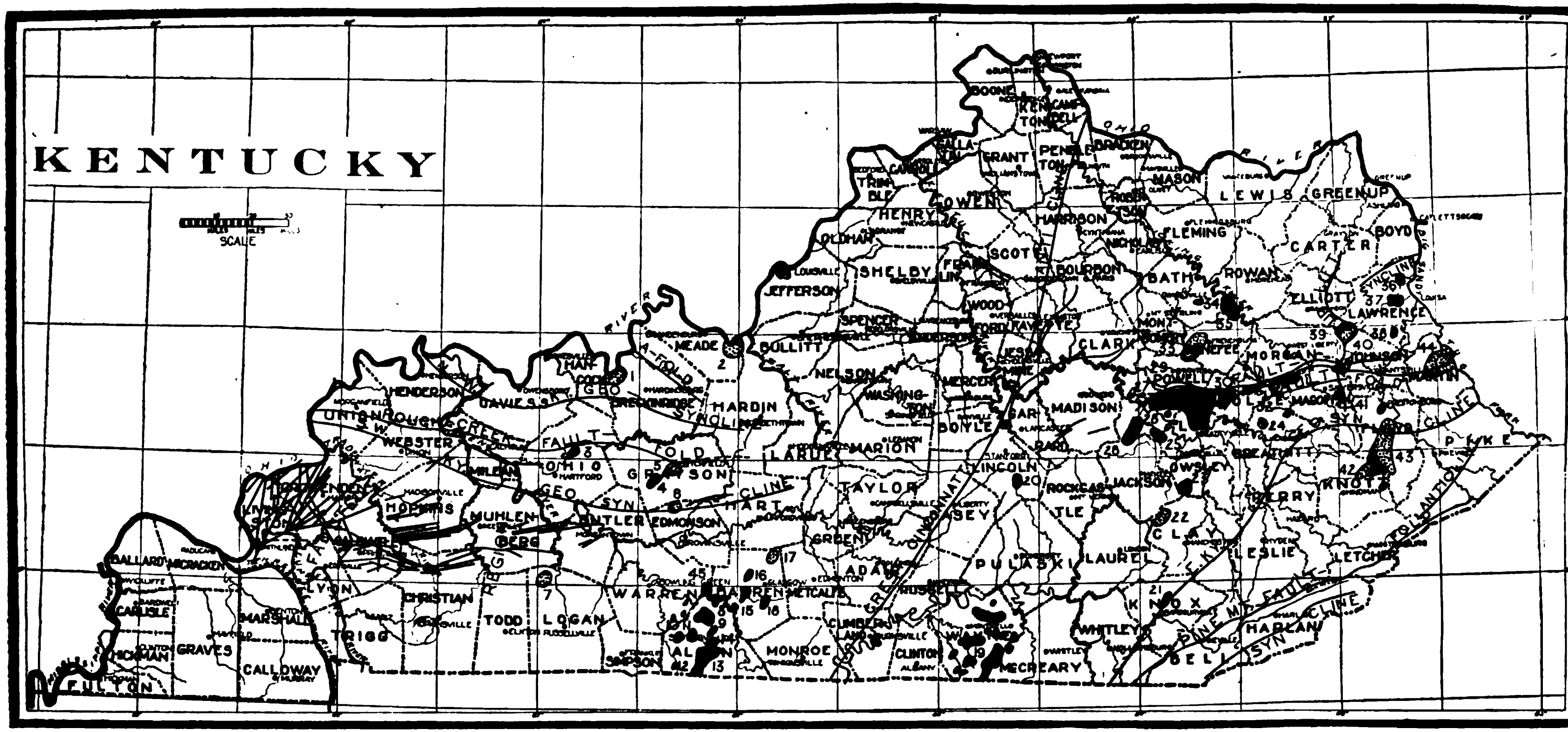
No.	Field Name	Producing "Sands"	County.
22.	Burning Springs Gas Field.	"Big Injun?"	Clay.
23.	Island Creek Oil and Gas Field.	"Onondaga?"	Owsley.
24.	Frozen Creek Oil and Gas Field.	"Onondaga"	Breathitt.
25.	Ross Creek Oil Pool.	"Onondaga"	Estill, Lee and Jackson.
26.	Station Camp Oil Pool.	"Onondaga"	Estill.
27.	Irvine Oil Pool.	"Onondaga"	Estill.
28.	Big Sinking Oil Pool.	"Onondaga"	Lee.
29.	Ashley Oil Pool.	"Onondaga"	Lee.
30.	Campton Oil Pool.	"Onondaga"	Wolfe.
31.	Stillwater Oil Pool.	"Onondaga"	Wolfe.
32.	Cannel City Oil Pool.	"Onondaga"	Morgan.
33.	Menifee Gas Field.	"Onondaga"	Menifee and Powell.
34.	Olympia Oil Pool.	"Onondaga"	Bath.
35.	Ragland Oil Pool.	"Onondaga"	Bath, Rowan and Menifee.
36.	Fallsburg Oil Pool.	"Berea"	Lawrence.
37.	Busseyville Oil Pool.	"Berea"	Lawrence.
38.	Georges Creek Oil Pool.	"Berea"	Lawrence.
39.	Laurel Creek Gas Field.	"Berea"	Johnson and Lawrence.
40.	Paint Creek Gas Field.	"Wier" "Berea"	Johnson and Magoffin.
41.	Ivyton Gas Field.	"Pottsville"	Magoffin.
42.	Beaver Creek Oil Pool.	"Beaver" "Horton" "Pike" "Maxon"	Floyd and Knott.
43.	Beaver Creek Gas Field.	"Beaver" "Horton" "Pike" "Maxon" "Big Lime" "Big Injun" "Berea" "Black Shale"	Floyd and Knott.
44.	Inez Gas Field.	"Big Lime" "Big Injun"	Martin.
45.	Moulder Oil Pool.	"Onondaga" "Niagara"	Warren.

First Published April, 1919.



SKETCH MAP SHOWING THE STRUCTURAL GEOLOGY OF KENTUCKY.

The solid patches show the location of the producing oil pool of the State. The dotted areas indicate the gas producing fields. Both oil and gas pools are numbered to correspond to local name key of text.

II.

The Used and Unused Natural Gas Fields of Eastern Kentucky and Their Relation to Present and Future Public Service Demands

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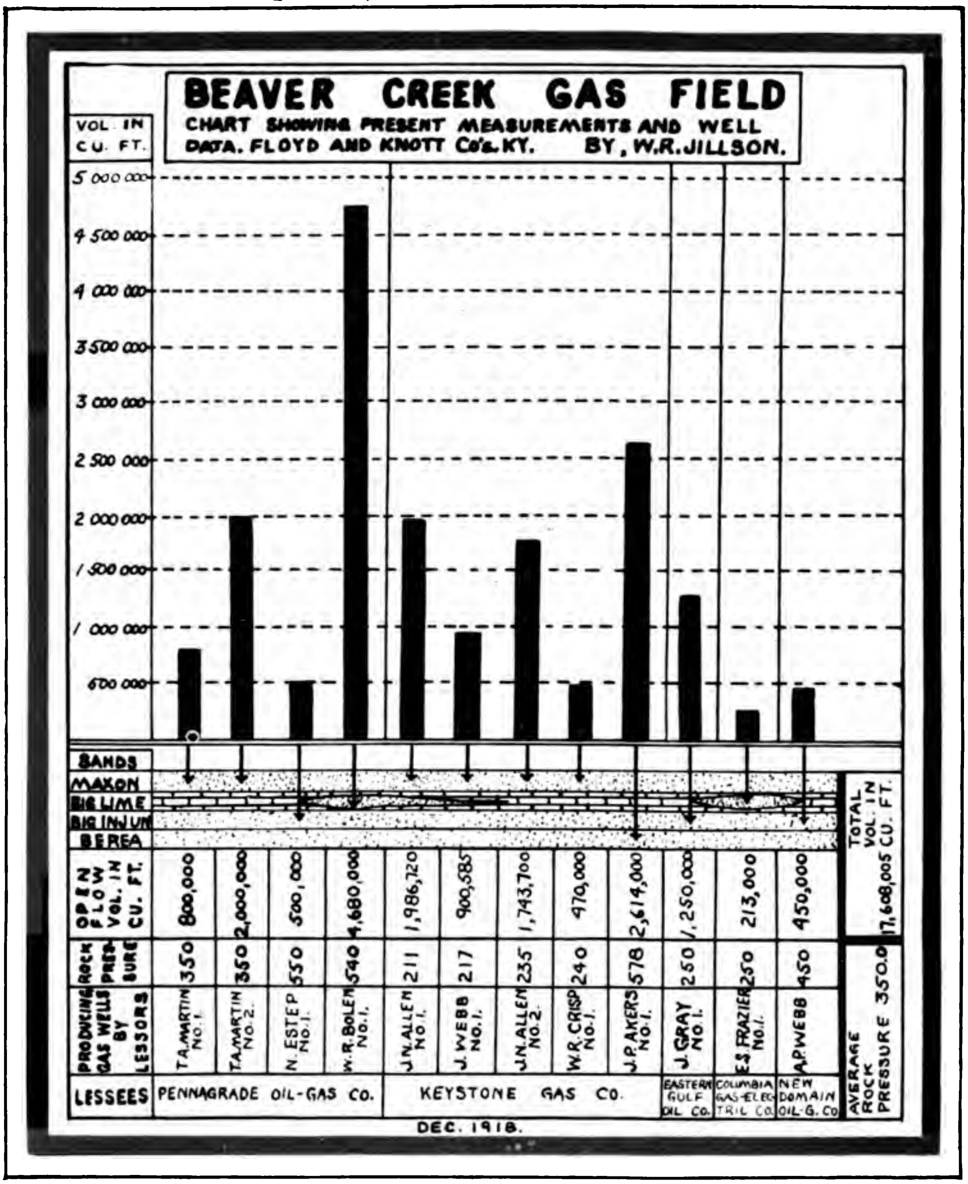
Within the last year much publicity has been given to the natural gas of Eastern Kentucky. Many written and verbal statements have been made as to its quantity, its accessibility, and its combustible qualities for the domestic purposes of fuel and light. As one can easily appreciate taking into consideration the broad range of authorities (everyone from the householder to the gas expert being included) much has been said that cannot be substantiated by actual investigation. On the other hand, many statements have been lean of the whole truth either due to ignorance or pessimistic predisposition. The present situation is such, therefore, that the interested public should take some thought as to a selection of the facts and figures presented, with a view to the throwing out of the extreme views, be they high or low. Only by such a method is it possible to secure a sane and practical view of the natural gas situation in the eastern part of this state today.

It was with the idea of (1) attempting some such sort of reasonable elimination of undependable facts, and (2) a coordination of those tatements and facts which merit acceptance that this paper was undertaken. As is now quite generally known the two largest developed natural gas fields of Eastern Kentucky are the Menifee and Martin County fields. The first of these fields, that in Menifee County, lies just east of the Central Blue Grass boundary. It is an old shallow field, the gas being taken from the "Corniferous" limestone which is the present oil producing formation of the Estill, Lee and Bath County fields to the south and northeast. Gas is secured at depths of from 450 feet to 680 feet, which made the field, from an optrator's standpoint, one of unusual attraction. Practically all of the gas produced by this field is used by the Central Kentucky Natural Gas Company which supplies the cities of Mt. Sterling, Paintsville, Winchester, Lexington, Paris, Midway, Versailles and Frankfort. Due to the heavy drain upon its

volume this field has greatly depreciated within the last few years and already other fields, now being developed in counties further to the east, are in progress of being coupled up to this line. The Martin County gas field, sometimes càlled the "Inez" field, after Inez, the county seat, and sometimes included with the adjoining West Virginia fields under the appellation of "Triple State Field," lies in the very eastern part of Kentucky between the Tug and Levisa Forks of the Big Sandy River. The Martin County field is also old gas territory, some of its first well having been drilled in 1897, or about twenty-two years ago. In contrast to the Menifee gas field, however, the Martin County field is a rather deep field, the productive gas sands being the "Big Lime" sand streak and the "Big Injun" sand. These formations average in depth below the surface between 1,100 feet and 1,500 feet. As may readily be seen, the greatly increased deeper drilling of the Martin County field made its exploration and development a much more costly and more hazardous undertaking than that of the Menifee field.

The United Fuel Gas Company undertook this work and today it owns and controls practically the entire supply of natural gas from this field. The effort of this producing company, always cautious yet businesslike, were rewarded by the successful development of the Martin County field a number of years ago to its maximum productivity of about 80,000,000 to 100,000,000 cubic feet in volume open flow of natural gas per day. Like the Menifee field, however, the Martin County field has been rapidly depreciating for several years both in volume of gas production and static or rock pressure of the gas. Its volume today is hardly a tenth of its maximum, and its rock pressure is less than two-thirds of what it was at one time. As shown by figures, the period of greatest depreciation has been since about 1907-1908, when this Kentucky Pipe Line feeding the city of Louisville was firt coupled on to the Inez station. With a continued heavy pull upon its resources the day marking the end of the commercial importance of the Martin County gas is rapidly approaching and it is only a matter of a short time when those lines which have secured their full or major supply from this field alone will be forced to turn to new developing fields.



Note:—This plate is taken from a private report on the Natural Gas of Eastern Kentucky, prepared by the author for the City of Louisville, in December, 1918.

It is fortunate with this kind of situation facing the gas consuming public of Kentucky that nature "did not put all of her eggs in one basket" or all of her natural gas resource in one geologic structural tank. It is also fortunate that the same discreet nature in making her original arrangements scattered her priceless supplies over a very broad area, thereby insuring, after the lesson of natural gas exhaustion of any particular field or fields through prodigal uses had been generally learned, a continued period of enjoyment with essential and regulated conservation, of the natural gas treasure. The facts in the case are these, that besides Menifee and Martin there are at least a full dozen counties in Eastern Kentucky which with careful scientific and systematic development may be looked upon as a great gas reserve, and one from which sufficient natural gas for conserved domestic consumption in Kentucky may be secured for a great many years. The question naturally arises how is it known that this is a fact, and why is not some of this vast supply of gas already being run into the underloaded commercial public service lines? The answers are many and varied, ranging from the cool scientific proof to the colder economic fact.

Since it is admitted by both the practical and the theoretical oil and gas producer that the drill is the ultimate agent in determining the occurrence of oil or gas in commercial quantity in the deep rocks, it will not be difficult for the layman to accept the facts presented by completed prospecting drillings in various parts of Eastern Kentucky. Without going into a length of tedious detail, which could scarcely add anything to the accuracy of this statement, it is a demonstrable fact that enough large gas wells have been drilled in Morgan, Lawrence, Elliott, Johnson, Magoffin, Floyd, Pike, Breathitt, Knott, Perry, Owsley, Wolfe and Knox counties to demonstrate beyond doubt the justifiableness of the claims of these above named counties to widespread recognition as a great untapped commercial natural gas reserve. In these counties absolute figures based upon accurate measurements will show at the present time not less and probably more than 40,000,000 cubic feet of natural gas in open flow at the tubing head. Eight gas structures alone in Eastern Kentucky taken together show a measured open flow volume of 28,230,000 cubic feet of natural gas. Out of this large amount

QUANTITATIVE EVALUATION OF TEN PROVEN NATURAL GAS STRUCTURES IN EASTERN KENTUCKY IN THE COUNTIES OF FLOYD, KNOTT, JOHNSON, MAGOFFIN AND MORGAN*

No.	Name of Structure.	Producing Sand.	Open Flow. Present By Gauge.	Etimated Possible Below Surface	Approx. Depth Open Flow
1	Rock Fork Monocline Knott County.	Big Lime	4,680,000	20,000,000	1,630
2	Beaver Creek Anticline. Floyd County.	Maxon-Berea	8,700,000	35,000,000	850-2,000
3	Steel's Creek Dome. Floyd County.	Maxon	2,800,000	8,000,00	900
4	Prestonsburg Anticline. Floyd County.	Wier-Berea.	500,000	2,000,00	1,428
5	Bull Creek Anticline. Floyd County.	Big Injun	1,050,000	6,000,00	1,300
6	Ivyton Dome. Magoffin-Johnson	Pottsville	500,000	3,000,000	350
7	Rockhouse Anticline. Magoffin County.	Berea Corniferous	....	7,000,00	1,500
8	Paint Creek Dome. Magoffin-Johnson.	Berea Corniferous	5,000,000 5,000,000	15,000,000	700 1,600
9	Laurel Creek Dome. Johnson County	Big Injun Berea		15,000,000	700-1,600
10	White Oak Anticline Magoffin-Johnson	Corniferous Big Injun Berea	....	10,000,000	600 1,500
	Total present Vol. open flow cu. ft.	....	28,230,000		
	Total estimated reasonably possible volume open flow in cubic feet........	....	....	121,000,000	

*NOTE.—The data presented in the above table is taken from a private report on natural gas of Eastern Kentucky prepared by the author for the city of Louisville in December, 1918. A few minor corrections have been made to bring the production figures up to date.

about three million feet has just recently been taken over by the Central Kentucky Natural Gas Co. Considered as a whole, however, of this forty million cubic feet "index" gas probably not one-tenth is serving any commercial purpose. The most of it remains "shut in" and unused, for the operators who drilled it in were searching for crude oil or petroleum and had no use for the gas. To what commercial maximum volume this "index" 40,000,000 cubic feet may be increased is at present impossible to say, but the figures will be many times greater than the "index" volume. The larger part of this gas is located at some distance from any public service trunk pipe line, and therefore is at present time of slight commercial importance except as an "index" to producing possibilities.

The demonstrableness of large amounts of reserve natural gas in Eastern Kentucky has within the past twelve months become generally accepted. And with the acceptance of this fact staring him in the face, the ultimate consumer, who experiencing some occasional inconvenience due to his inability to get gas in the quantities he desires during periods of unusually sever climatic conditions, finds himself somewhat in the same state of mental confusion as that attributed to the thirsty Ancient Mariner, for with "natural gas most everywhere, there's not a bit to burn." The real danger point in the whole natural gas consumption question then finds its focus here. The consumer being told there is plenty of gas believes it and has not been able to understand why he cannot have the little he wants to use. The gas distributing company being told there is plenty of gas to be had believes it, and yet cannot find ready solutions to problems of legal agreements and widespread and extremely costly trunk pipe line extension.

The general lines of final adjustments of the many nationwide disagreements over the supply of municipal natural gas may now, however, be forecast, for the most of them will necessarily be effected in the near future. In the particular case of the city of Louisville, Kentucky, the Louisville Gas and Electric Company, adjusting its vision to a rapidly expanding municipal consumption will exert every endeavor to increase its public service burden and meet a just and reasonable demand. The citizen of Louisville, on the other hand, expanding his

A 60-HOUR BLAZE AT WOLF COAL.

Scene during the sensational fire which followed the explosion of the Big Bird Oil Company's test on Wolf Creek, Breathitt County, Ky., November, 1918. Photo by R. A. Chiles.

vision to a realization that natural gas, always handled with difficulty and until recently rightly considered a genuine luxury, is still such. Like all other greatly prized physical things, existing in an exact and unrenewable quantity, it must be used sparingly as befits a luxury, and continually conserved that the delimited period of the enjoyment of its priceless advantages of cheapness and convenience may be prolonged measurably into the future, beyond the prodigal demand of today.

First Published April, 1919.

III.

Structural Deformation and Its Relation to Proven Oil and Gas Accumulation in Eastern Kentucky.

INTRODUCTORY.

The sedimentary rocks of Eastern Kentucky, like those of the adjoining state of West Virginia, have long been known to contain many anticlinal and synclinal folds. A number of these are in fact nothing more than continuations of folds which are well known, named and mapped in West Virginia. All of three folds even westward as far as the Central Blue Grass section are probably the result of the same forces—strong crustal pressures exerted from the southeast in Post-Pennsylvanian times—that produced the major folding and faulting of the sister state of West Virginia. To date, little or no attempt has been made to map these interstate and associated structures in Eastern Kentucky. It is the purpose of this paper to show by sketch map the interlocking nature of some of the more important of these folds. and present briefly their established relationship to the proven oil and gas pools of this part of the state. The information presented in this paper is based upon data and notes taken by the author in the field during the summer and fall of 1917, and the full field season of 1918. The area referred to is that shown by the map (Fig. 1), and is roughly the quadrangular section enclosed by Montgomery, Knox and Pike counties, Kentucky, and Mingo, West Virginia.

STRUCTURAL AND STRATIGRAPHIC GEOLOGY.

A birdseye view of the geologic structure of this part of Eastern Kentucky throws into immediate relief two major interstate features, (1) the Pine Mountain Fault and Fold, and (2) the Irvine-Paint Creek-Warfield Fault and Fold. Each of these features occupies an outstandingly high structural position in the Kentucky sediments from which strata dip away into geosyncline in either direction. A closer examination of these flanking areas shows them to be deformed into a great number of smaller folds of only local importance. Occasionally small

Drilling in Buck Creek Pool.

Though the size of this oil pool is relatively small drilling is going rapidly ahead within the proven areas, the Onondaga Limestone (Irvine "sand") being found at between 225,300 feet below the surface. Photo by W. R. Jillson, Mar. 20, 1919.

Down in Big Sinking.

View of drilling on the George Booth farm by the Quaker Oil Company in the creek bottom. Photo by W. R. Jillson, April, 1919.

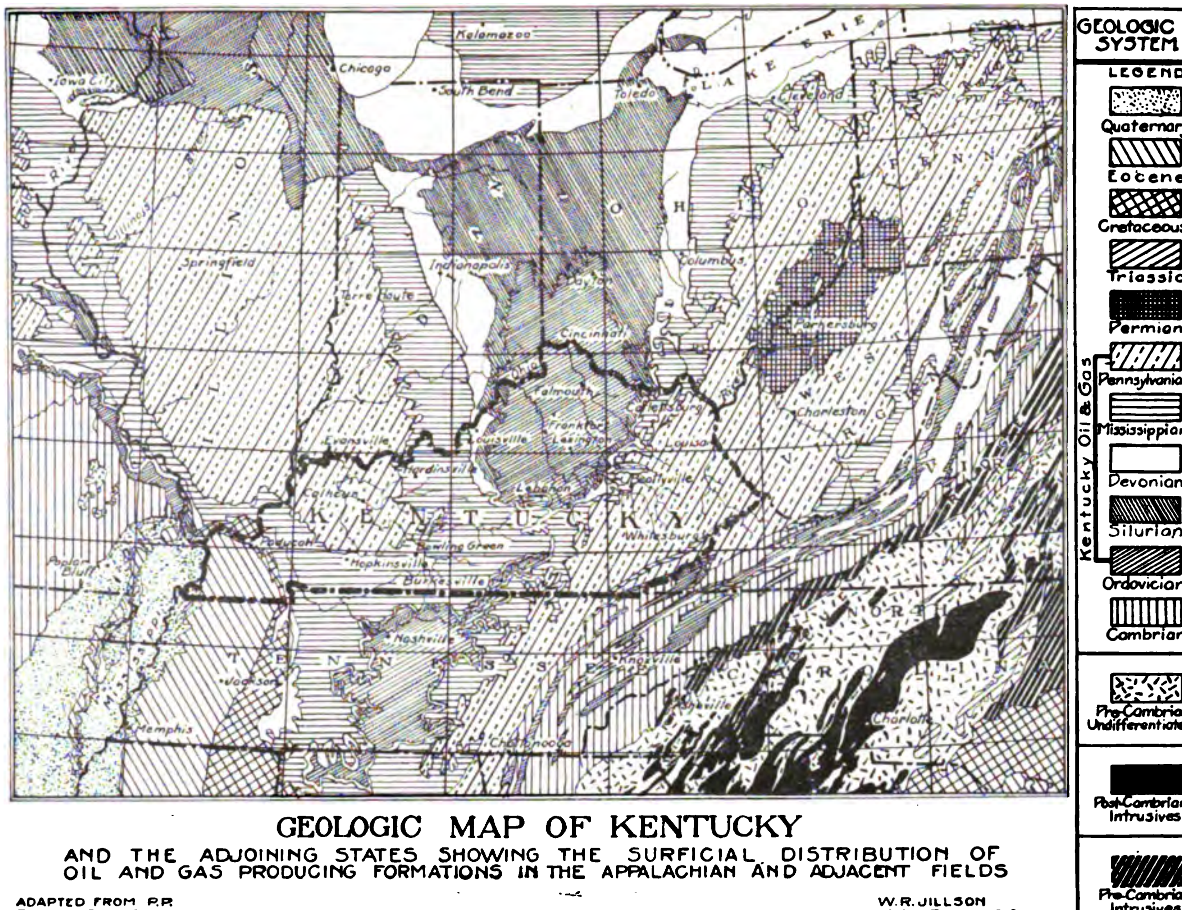
faults are found in this area whose importance is directly comparable only to those pigmy structures which adjoin them. Altogether these associated larger and smaller structures because of their location in the southern portion of the Appalachian Oil and Gas field have afforded many difficult problems to both oil operators and geologists. The fact that the surficial rocks are almost entirely Pottsvillian—famous for their extreme irregularity—has added to, rather than lessened the stratagraphic and structural confusion. The northwestern part of the area shows the Conglomerates of the Lee Formation. These are adjoined on the southeast by the sandstones, shales and coals of the Norton lying as a relatively narrow belt along a northeast-southwest line. Considerably over half the area—the southern and eastern part —is composed of that great succession of sandstones, shales, impure limestones, and commercial coals which make up the Wise or Upper Pottsville. A number of the very highest points in this latter area are capped by a relatively thin blanket of similar sandstones, shales and coals which have been referred to the Alleghany Formation. The Pennsylvanian sediments of Eastern Kentucky have never been differentiated and mapped, except in very small restricted areas, so it is impossible to outline more definitely the aerial geology of this section.

Underlying these exposed Pennsylvanian rocks are the unexposed representatives of the Mississippian, Devonian, Silurian and Ordovician systems. This much has been confirmed by a large number of test drillings. Whether the Cambrian underlies all of this area is not definitely known as these rocks, especially in the southern and eastern regions, are very deep—probaly in some sections over a mile below the surface. And what lies below the Cambrian in this or any other part of Kentucky no one knows in spite of the ten thousand oil wells that have been drilled in the state.

Structural Features in Detail.

The Pine Mountain Structure.

The Pine Mountain Fault and Fold—one of the two real mountains of elevation in Kentucky—lies partly along the southeastern boundary of Kentucky and marks the limit of the discussion of this paper in that direction. It is essentially a great overthrust fault in Bell and Letcher counties which in going



GEOLOGIC MAP OF KENTUCKY

AND THE ADJOINING STATES SHOWING THE SURFICIAL DISTRIBUTION OF OIL AND GAS PRODUCING FORMATIONS IN THE APPALACHIAN AND ADJACENT FIELDS

ADAPTED FROM P.P. 71, U.S.G.S., BY W. R. JILLSON LEXINGTON, KY. 1918.

northeastward into Pike County passes into a faulted fold of large proportions as it leaves the state in its extension into Virginia. In Bell and Letcher counties it passed steadily through simple and overturned anticlinal features into those of fracture and overthursting. Through this sequence of structural changes the extreme pressure exerted from the southeast was gradually decreased. The great significance of this release of pressures will be appreciated when it is understood that it undoubtedly marked the end of the development of all the other smaller structurss of the area.

During the time of the overturning of the Pine Mountain Fold and just prior to the break and overthrusting, many small anticlines and minor faults were developed, with major axes angulating from or nearly parallel to the large structure. This condition of somewhat widespread fracturing and sharp folding has apparently resulted in great damage to this area as an oil and gas reservoir, since to date no commercially successful wells have been drilled in this area. In Knox County the Artemus-White Mountain Anticline, and in Pike County the D'Invillier Anticline have as yet—though with only a slight amount of drilling—proven dry.

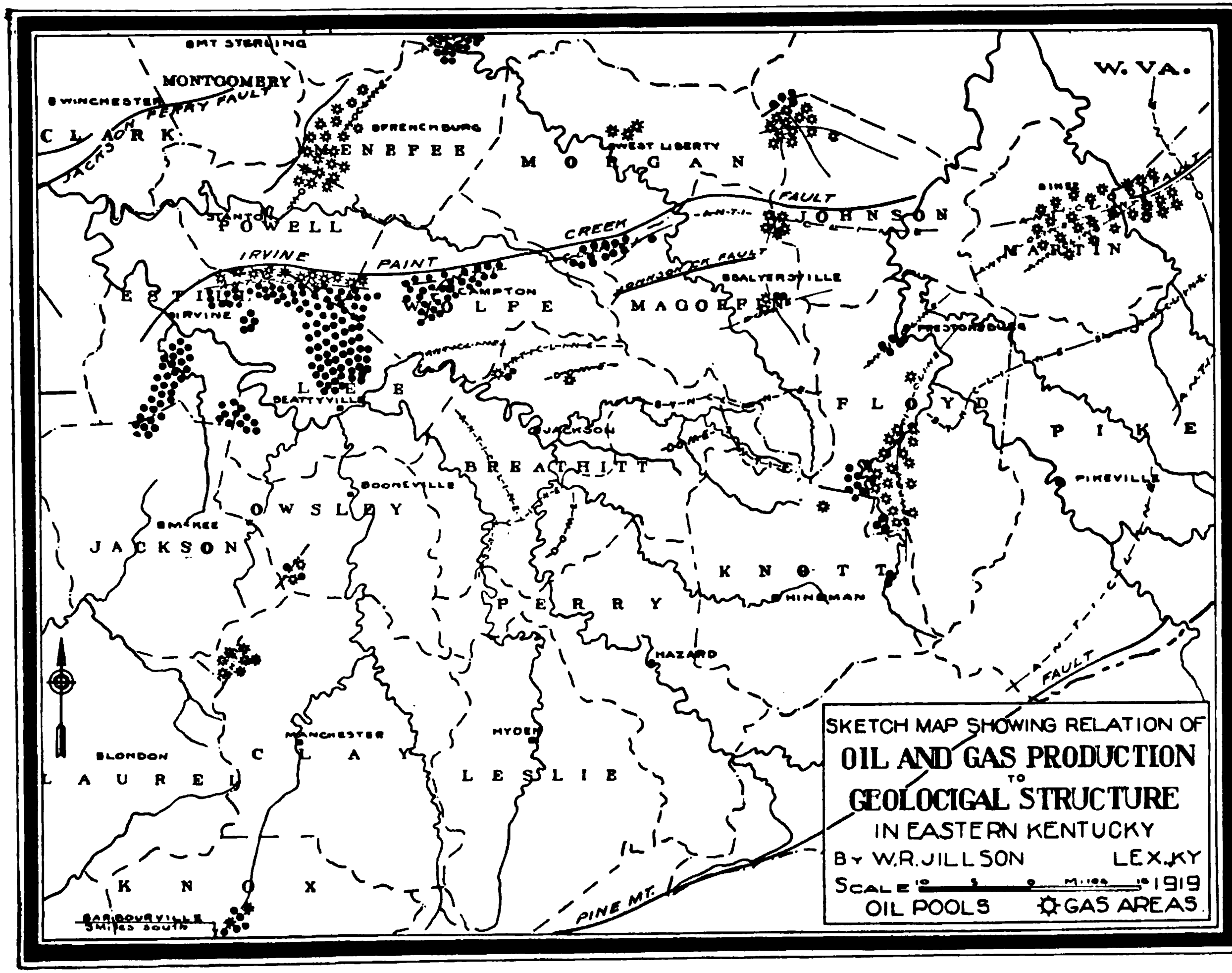
The Irvine-Paint Creek—Warfield Structure.

Second to the Pine Mountain structure in point of size, the Irvine-Paint Creek-Warfield structure (fault and fold) has, as is generally known, proven itself to be of the very first importance from the standpoint of oil and gas accumulation and recovery. This structure in its varying expression is largely a normal fault in the west with throw up to 150 feet. The fault proper extends from near Irvine east to the Big Sandy river, in Johnson County. It crosses in part or in whole the counties of Estill, Powell, Wolfe, Morgan, Magoffin and Johnson. In Martin County this structure is a well defined anticlinal fold which extends eastward into Mingo County of West Virginia, and soon assumes a faulted condition along or near its crest. Like the Pine Mountain fold this large structural feature has smaller radiating and parallel structures adjoining it. It is these smaller, and some times almost impreceptible structures which have proven the seats of Kentucky's most important oil and gas pool. These are: (1) Station Camp, oil; (2) Irvine, oil; (3) Ross Creek,

oil; (4) Big Sinking, oil; (5) Ashley, oil; (6) Campton, oil; (7) Cannel City, oil and gas; (8) Paint Creek, gas, and (9) Laurel Creek oil and gas, and (10) Inez, gas.

Minor Structures.

Between these two structures there are a large number of folds, much maller in size, which have been prospected for oil and gas with varying results. In Clay and Owsley counties there is an anticline with two dome-like humps on it which has proven gassy in Clay. In Owsley, just to the north, this structure shows both oil and gas. In Breathitt County there are five pronounced structures—two anticlines and three domes. Two of these, the Wilhurst or Frozen Creek Anticline, oil and gas, and the Cope's Fork Dome, gas, have been proven. The other three structures have not been tested either at all or adequately. In the southern edge of Wolfe County there is an anticline of rather small proportions—the Holly Creek Structure—that has been proven dry. In Magoffin County, just east of the Licking River and south of the Fault, between the Cannel City structure and the Paint Creek Dome (gas), there is a structure known as the Rockhouse or Raccoon Anticline that is as yet virgin. Southeast of Salyersville lies the Ivyton Dome, a small somewhat symmetrically contoured structure which has been proven (in the Pottsville) to contain small gas and low gravity black oil. In Knott County there is at least one structure of outstanding importance—the Yellow Mountain Anticline—which on its eastern flank has proven gassy. In Floyd County there are two structures (1) the Prestonsburg Anticline, and (2) the Beaver Creek Anticline, which are becoming well known. The first of these has proven oil of small quantity in the Weir or Berea "sand," and the second has proven both oil and gas with a stratigraphic range from the Pottsville down to the Black Shale of the Devonian. Berea oil and gas on this structure has been erroneously reported due to faulty correlations. Pike County, as before stated, has to date —in spite of the D'Invillier Anticline, which in its northeastward extension, passes into West Virginia as the Williamson Anticline—proven unproductive. In Johnson County, south of the Fault and closely associated folds, and with the exception of the Paint Creek Dome, there is no other structure of rank.


SKETCH MAP SHOWING RELATION OF
OIL AND GAS PRODUCTION
TO
GEOLOGICAL STRUCTURE
IN EASTERN KENTUCKY
BY W.R. JILLSON
LEX. KY
SCALE
MILES
1919
OIL POOLS
GAS AREAS
W. VA.
MONTGOMERY
MT STERLING
WINCHESTER
CLARK
FERRY FAULT
JACKSON
MENEFEE
FRENCHBURG
MORGAN
WEST LIBERTY
JOHNSON
FAULT
MARTIN
POWELL
STANTON
IRVINE
PAINT
CREEK
ESTILL
WOLFE
CAMPTON
MAGOFFIN
SALYERSVILLE
PRESTONSBURG
LEE
BEATTYVILLE
FLOYD
PIKE
PIKEVILLE
BREATHITT
JACKSON
BOONEVILLE
OWSLEY
MCKEE
KNOTT
HINDMAN
PERRY
HAZARD
HYDEN
MANCHESTER
LONDON
CLAY
LAUREL
LESLIE
KNOX
BARBOURVILLE
5 MILES SOUTH
PINE MT.

Heart of the Buck Creek Pool.

Within the proven area of this small Lincoln County oil pool no dry hole has ever been drilled. The Daniel Boone Oil Company pipe line takes the production of this entire pool to tank car station at Kenor's Mountain Station. Photo by W. R. Jillson, Mar. 20, 1919.

Martin County is crossed along its middle part by the Warfield Structure, which produced the famous Martin County or Inez gas field. Small shows of oil were encountered in some of these gas wells.

North of the Irvine-Paint Creek-Warfield Structure, in the relatively small area enclosed within this paper, there are only three structures of importance and all of these have proven productive. Thees structures are, in Menifee and Powell counties—just northeast of the Irvine section—(1) the Menifee Anticline, gas; and further to the northeast (2) the Ragland Anticline, oil; and in Johnson, Morgan and Lawrence counties (3) the Laurel Creek Dome, oil and gas.

Summary of Relationships.

A consideration of actual field conditions as outlined briefly above establishes beyond doubt a close relationship between geologic structure and proven oil and gas areas in Eastern Kentucky. This relationship may be expressed as follows: (1) oil and gas occur in commercial quantities chiefly along anticlines which in this section may be divided into two classes on a basis of their

Tank Oil Going to Louisville.

Louisville & Nashville Railroad train of fifty tank cars filled with Kentucky crude oil en route from the Lee-Estill field to refineries in Louisville. Partial view of train only, taken in Frankfort in front of Old Capitol. Photo by W. R. Jillson, April 16, 1919.

Lewis Pump Station.

This station is located in Morgan County, Kentucky, and is part of the new pipe line equipment of the Cumberland Pipe Line Company. Photo by W. R. Jillson, 1918.

size and structural importance. (2) Gas is usually found at the highest points of the structures—especially when the structures are closed or domed—though occasionally these highest points may be dry. (3) Oil is found to occur on the flanks of the larger anticlines just below the gas belts, and on the smaller anticlines frequently up to and over crestal points. However, occasionally due to geologic conditions—(A) unconformable strata and (B) tightening "sands"—not apparent at the surface, the "pay" belt may be so low structurally as to be confused with the observed synclinal area. (4) Dry holes are rare in Eastern Kentucky, and are usually found to be located in the known synclinal areas though they may occasionally occur high on—(A) faulted or (B) sharply folded anticlines. (5) The best oil and gas production is found without exception along the largest and most pronounced anticlines. (6) The opposite is true, that is, the smallest structures show no wells producing either oil or gas in important commercial quantities. (7) The best oil and gas production has been developed along structures separated by wide synclinal areas, which apparently afforded the source for the accumulation of the hydrocarbons.

A broad conception of the structure of this part of Eastern Kentucky, coupled with the known distribution of the oil and gas field either wholly developed or in process, suggests a definite sequence of events. These are: (1) The printed and simultaneous development of the Irvine-Paint Creek-Warfield Structure and the Pine Mountain Structure, with an attending further uplift along the Cincinnati Arch to the west. (2) The general concurrent migration of the various petroleums away from the Pine Mountain structure and the southeastern geo-syncline toward the Irvine-Paint Creek-Warfield Structure at the northwest. (3) The secondary development of many intermediate small structures in the geo-synclinal strata of only light petroleum productive capacity. (4) The overturning, faulting, and thrusting of the Devonian to Pennsylvania sediments in the Pine Mountain Area which produced a condition of equilibrium in the crustal forces, and essentially terminated the period of structural growth. (5) Continued to final adjustment of all free hydrocarbons according to hydrostatic or hydraulic pressures.

CONCLUSIONS.

The large amount of wildcat drilling done in Eastern Kentucky during the last two years has permitted the determination of the presently considered productive and unproductive areas. An investigation of the location of these productive and unproductive areas operates as a substantiation of the anticlinal theory of oil and gas accumulation. Much unproductive drilling could have been avoided by an advance knowledge of structural conditions. A more widespread and careful use of sound structural interpretations will also avoid many unnecessary expenditures of this kind in the future. A great many apparently excellent structural locations still remain to be drilled and redrilled from shallow "sands" to greater depths in Eastern Kentucky.

First Published July, 1919.

IV.

The Status of the Mauch Chunk in Southeastern Kentucky As A Producer of Petroleum and Natural Gas.

INTRODUCTORY.

During the pat year with the steady increase in oil and gas prospecting in Johnson, Martin, Floyd, Knott, Perry and Knox counties there has developed considerable interest in the number and sequence of the oil and gas producing "sands" in this section of Kentucky. Because of the variability of the Lower Pottsville sediments and the great unconformity between them and the underlying Mauch Chunk, much uncertainty has arisen in the correlation of producing sands. Since the principal oil production of this area comes from the basal Pottsville and Mauch Chunk the interest chiefly centers about these horizons. It is the purpose of this paper to bring together the data of both new and old drilling in this section and offer by such means an interpretation of the actual conditions existent in the subsurface stratigraphy. The field work upon which these conclusions are based was carried on intermittently over a period of two years—1917 and 1918—during which time all the principal producing and wild catting localities of this part of the state were visited.

STRATIGRAPHY.

The surficial rocks of Johnson, Martin, Floyd, Knott, Perry, and Knox counties, Kentucky, are of Pottsville age. The same is true that Pike County with the exception of that portion along the Pine Mountain Fault, where through over-thrusting the underlying Mississippian formations are brought to the surface. Johnson County shows Middle Pottsville or representatives of the Norton Formation in the western and northwestern portions. The eastern and southern parts of this county, due to the pronounced dip in these directions, show only the upper Pottsville above the Big Lime. These have all been correlated as belonging

or Wise Formation. This formation is commonly known in West Virginia as the Kanawha. The Upper Pottsville rocks are also surficially exposed in Floyd, Martin, Knott, Perry, Knox and also in Pike, with the exception of the Pike Mountain locality.

Oil and gas operators in this field generally spud into rather thin creek or river bottom soil of the Coal Measures. All drill records that are carefully kept will show from two to four and sometimes six coal seams of varying thickness before the bit strikes the first limestone. This first limestone—sometimes only a calcareous shale and therefore often recorded as a shale —is generally an upper member of the Mauch Chunk. It represents the break or change from the heterogeneity of conglomeratic sands and shales and overlying coal seams of the Pottsville, to the more uniform alternation of sands, shale and limes of the Mauch Chunk. In a way it anticipates a growing limy condition as the bit goes down, which culminates within a short distance in that well known drilling horizon the "Big Lime" of the Mississippian System.

Drillers operating in the Upper Big Sandy Valley have definitely determined four separate and generally distinct sands

Hauling a Rig in the Big Sandy Valley.

Eastern Gulf Oil Company moving its heavy National rig over very poor roads from Bull Creek to Left Middle Creek, Floyd County, Ky. Photo by W. R. Jillson, March, 1918.

in the Pottsville.* They are regarded as a splitting up of the thinner Pottsville of the northeastern part of the state and are named in descending order, Beaver, Horton, Pike and Salt Sands. Three Pottsville sands are also listed in the Knox County, Little Richland Creek section. These in descending order are the Wages, Jones and Epperson. The following table of this upper portion of the Paleozoic Sediments of Kentucky has until recently been considered correct:

KENTUCKY SERIES AND CORRESPONDING OIL SANDS*

System.	Series.		Remarks
Pennsylvanian	Conglomerate Measures Shales, Coals Massive	Beaver, Horton, Pike, Salt } of Floyd, Pike, etc. — Wages, Jones, Epperson } of Knox	Corres ponds in part to Pottsville Conglomerate of Ohio, West Virginia and Pennsylvania.
Mississippian	Chester Group. Shales, Limestones and Sandstones.	None known as yet	Corresponds to Mauch Chunk of West Virginia and Pennsylvania.
	St. Louis Group. Mostly Limestones.	None known except where broken by an intervening sand in Pike and Martin Counties.	Corresponds to Mountain Lime, Big Lime and Green Briar Lime.

(Lower part of the original table omitted because of irrelevancy.)

*J. B. Hoeing, Oil and Gas Sands of Ky. Bull. 1, Ky. Geol. Surv., 1905, p. 12.

The Mauch Chunk.

According to this correlation it can be readily seen that the principal production of this portion of Kentucky is ascribed to the Pottsville. A consideration of the facts revealed by the somewhat extensive recent drilling of this section does not apparently substantiate this view any longer. It has been found by constructing a detailed section of six new and carefully kept well logs from a point on Mud Lick Creek, west of Paintsville, central Johnson County, to Wheelright, on the head of Otter

*J. B. Hoeing—Oil and Gas Sands of Kentucky. Bull. 1, Ky. Geol. Surv. 1905, pp. 12 and 13.

Creek of Left Beaver Creek, in the southern nipple of Floyd county, that the true Mauch Chunk is present at all points south of Prestonsburg. Furthermore in this region the Mauch Chunk shows a very striking resemblance to its described typical occurrences in the adjoining state of West Virginia. There recent wells, which show such splendid representation of the Mauch Chunk, are, going south in Floyd county, the Joseph Gray No. 1, Bull Creek, J. M. Akers, No. 1, Left Beaver, Frazier No. 1, Left Beaver and the Elkhorn Coal Corporation No. 1, Wheelright. Each of the logs shows a sandstone varying from 50 to 100 feet thick overlain by red shale from 10 to 50 feet thick and underlain by an impure limy shale—the Pencil Cave.

In a letter to the writer under date of March 4, 1919, Prof. I. C. White, State Geologist of West Virginia, says in part:

> "I would say that nearly everywhere in West Virginia we have a well-defined sand in our Mauch Chunk Series. It was first discovered near Sistersville, Tyler County, West Virginia, and named the "Maxton" Sand from its discovery on the land of a farmer named Maxton. It has proven productive over a considerable area and always occurs a short distance below the top of the first Red Beds below the Pottsville conglomerate while the Pencil Cave is practically universally present below the Maxton Sand and immediately on top of the main Green-briar or Mountain limestone. Hence, if you find a productive sand in eastern Kentucky section at the horizon in question and Red Beds above and Pencil Cave below, it would represent our Maxton Sand of the Mauch Chunk Series of Chester Group."

A further inquiry into the records of a large number of very old wells, many of which were drilled into this section before it was as well known as at present, reveals the rather startling fact that the Mauch Chunk sequence of (1) Red Rock, (2) Sandstone, (3) Limy shale was encountered in widely separated places. It shows great variability both in known thickness ranging from 9 feet in Floyd County to 274 feet in Martin. The shallowest depth at which the red rock was encountered is 872 feet in Floyd and the deepest 1566 in the same county—southern part. These old records as excerpted* are presented herewith for individual study.

*J. B. Hoeing—Oil and Gas Sands of Ky. Bull. 1, Ky. Geol. Surv., 1905, pp. 84-93, 161-179, 80-84, 94-97, 180-182, 103, 107.

Floyd County.

	Waters	Depth to Red Shale.	Known* Thickness
Joseph Gearhart	Salt Lick Creek	1,158	14
Susanna Gearhart	Right Beaver—Salt Lick	1,053	49
James Prater	Brush Creek	931	228
G T. Kendrick	Cow Creek	1,143	267
Joseph Gray	Bull Creek	900	130
Marion Rice	Brush Creek	1,020	13
Jack Allen	Salt Lick	1,126	9
George Allen	Right Beaver—Salt Lick	1,045	134
R. S. Elliott	Mud Creek	1,566	195
A. S. Crisp	Buck's Branch	930	131
T. J. Webb	Henry Branch—Beaver Creek	872	253

Martin County.

Jack Cassidy	Hardin Branch—Coldwater Fork	1,050	140
Burning Well	Tug Fork—Big Sandy	764	274
Sam Munsey	Big Branch—Wolf Creek	1,010	225
J. M. Stepp	Wolf Creek		160

Pike County.

Schomberg Well	Caney Fork—Johns Creek	1,336	164
	Cedar Creek	1,211	139
May	Bear Fork—Robinson Creek	1,490	102
Flem Maynard	Brushy Fork—Johns Creek	1,312	254

Knox County.

Madeline Gray	Gray's Station	910	268

Whitley County.

L. E. Bryant	Pine Knot	807	93

In order to show the stratigraphic sequence of the Potts-ville-Mauch Chunk Sediments in the Big Sandy Valley and the rapid thickening of these upper formations to the east, two well

*The bit in all of these instances probably did not pierce the entire Mauch Chunk and therefore the thinnest thicknesses given may involve slight error.—W. R. J.

kept logs have been selected and are presented. The first is a rather recent drilling near Prestonsburg, Floyd County, the second a very much older drilling on Big Branch of Brushy Fork of Johns Creek, Pike County.

Log. No. 1. Illustrating the Pottsville-Mauch Chunk. Joseph Gray No. 1. Bull Creek, Floyd County, Kentucky.

Stratum.	Thickness.	Depth.
Soil, 10" Casing	14	14
Pennsylvanian System.		
Sand and shale	26	40
Coal, water	4	44
"Pottsville" conglomerate	211	255
Shells, shale	55	310
Sand	90	400
Shale, shells	100	500
"Beaver" sand	200	700
Small gas at 625.		
Slate and coal	24	724
Slate, and sandy shale	118	842
Water at 756.		
Sand	78	920
Mississippian System.		
"Red Rock" shale	30	950
Shale	41	991
"Maxton" sand—Gas small	93	1,084
"Little" lime	24	1,108
Pencil Cave (Black slate)	15	1,123
"Big Lime," St Louis	152	1,285
"Big Injun" sand and shale, Gas production 1,300	40	1,325
"Waverly" shale	255	1,580
Brown shale	20	1,600
"Berea" or "Weir" sand shell (gas and oil show)	80	1.680
Devonian System.		
Brown shale	120	1,800
Gray slate	15	1,815
Brown shale	595	2,410
"Corniferous" limestone	30	2,440

National Rig. T. M. King, Driller.

Log. No. 2. Illustrating the Pottsville—Mauch Chunk. Flem Maynard No. 1. Big Branch of Brushy Fork of Johns Creek, Pike County, Kentucky.

	Thickness.	Depth.
Drift	9	9
Sand	4	13
Light slate	27	40
Gray sand	54	94
Dark slate	11	105
White sand	37	142
Dark slate	62	204
White sand	30	234
Black slate	16	250
Coal	3	253
Light slate	7	260
Gray sand	105	365
Dark slate	31	396
Coal	4	400
Dark slate	10	410
Gray sand (salt water)	18	428
Light slate	15	443
White sand	21	464
Dark sand	28	492
Black slate	70	562
White sand	21	583
Slate	208	791
White sand (gas and salt water)	251	1,042
Black slate	13	1,055
Blue sand	12	1,067
Black slate	68	1,135
Sand (gas and salt water)	88	1,223
Dark sand	8	1,231
White sand	56	1,287
Coal	1	1,288
Base of Conglomerate Measures.		
Sand	24	1,312
Red shale	12	1,324
Sandy slate	15	1339
White sand "Maxon"	61	1,400
Lime	12	1,412
Slate	8	1,420
White sand "Maxon"	49	1,469
Dark sand	28	1,497
Sandy slate	24	1,521
Gray sand	18	1,538
Sandy slate	27	1,566
Lime (red shale at base)	214	1,780
Blue sand	20	1,800
Slate	410	2,210
Dark-brown slate	47	2,257

SUMMARY.

In conjunction with the above data, which removes any doubt as to the presence of the Mauch Chunk in more or less typical expression in this part of Eastern Kentucky, there are a large number of wells in this section that do not show a red rock cap. These same wells, however, generally show a dark drab to black cap shale over a white sand which seems to be identical with that beneath the regular red rock cap. This white sand, which has been called the "Salt Sand" of the Pottsville, is productive of both oil and gas. It is the writer's opinion that this sand is not Pottsville at all, but the "Maxton" (Maxon of Drillers), as recognized in West Virginia. The chief proof substantiating such a view is the widespread distribution in this southeastern section of the state of the typical Red Rock—Sandstone—Pencil Cave sequence. The variation in thickness of the Mauch Chunk, as far as known, gives the clue to the proper explanation of the absence of the red rock cap at some places and the presence of darker shale. This explanation is the great unconformity at the top of the Mauch Chunk. Had this unconformity not become developed to the degree in which we now know it there is no reason to doubt but that the red cap of the Mauch Chunk sand would have been more widely and uniformly distributed. North and west of Prestonsburg the Mauch Chunk is recognized with difficulty as a very thin remnant or is entirely missing. South, east and west of the same town the "Maxon Sand" is genarally well developed as well as the red cap rock. In the Beaver Creek section of Floyd County the "Maxon Sand" is both an oil and gas producer. About sixteen old and new wells are producing crude from this horizon, and about fourteen are now producing gas from the same sand.

CONCLUSIONS AND CORRECTIONS.

Occasionally a section is found where four distinct and separate sands are developed in the Pottsville. Such a case is the Maynard well, of Pike county. Usually, however, there are only four separate sands above the "Big lime." The lowest of these which has been considered Pottsville and called "Salt Sand" must in most cases be reclassified as "Maxton" of the Mauch Chunk. Such definite conclusions then give the following stratigraphic table:

CORRECTED SEQUENCE

South Eastern Kentucky Series and Correlated Oil Sands

System		Sands	Correlation
Pennsylvanian	Coal Measures Conglomerates Shales, Sandstones.	Beaver, Horton, Pike of Floyd, Pike; Wages, Jones, Epperson of	Pottsville Conglomerate of Ohio. West Virginia and Pennsylvania.
		Great unconformity	
Mississippian	Chester Group Shales, Impure Limestones and andstones.	Maxton:—Of Martin, Floyd, Pike and Knott. The principal producer of oil and gas in this section.	Mauch Chunk of West Virginia and Pennsylvania.
	St. Genevieve St. Louis	"Big Lime Gas Sand"	Mountain Lime. Green Briar Lime.

(Lower section omitted because of irrelevancy.)

Whether future drilling will ever demonstrate the practicability of a correlation of the "sands" of the Pottsville of the Floyd-Pike section with that of Knox remains to be seen. As far as the "Maxton" is concerned it is doubtful if it can ever be recognized as far as to the west of Knox County, as the Mauch Chunk, though typically represented by the red shales, is rapidly losing its sandy phase and taking on the characteristic of the limy and shaly Chester of central, southern and western Kentucky.

First Published July, 1919.

V.

The Kendrick Shale—A New Calcareous Fossil Horizon In the Coal Measures of Eastern Kentucky.*

Introduction.

In August, 1918, while engaged in doing oil and gas structural geology in Kentucky, the writer discovered a new fossiliferous limestone shale horizon on the head waters of Cow Creek, Floyd County, Kentucky. A rapid reconnoissance of the typical outcrop in this locality led to immediate conclusions that the horizon presented features of paleontologic value worthy of more extended study. Subsequent field investigations carried on by the writer have more than justified this decision. It definitely appears now that, besides opening up new avenues of paleotologic investigations, this limy shale horizon, which has been called the Kendrick shale, may when coupled with other similar horizons known to exist in this section, and certain definite coals come to be regarded as of fundamental importance in determining the unmapped stratigraphic geology of this part of Kentucky.

The work already done and the results herewith presented are therefore to be considered simply as preliminary to a more exhaustive investigation which is now under way. There is no published literature which may be regarded as having any direct reference to this Kendrick limy shale horizon or its fossil content. The fossils are new and unmatched as a collection either in or outside of the state of Kentucky. The determinations and conclusions herewith presented may therefore be taken as independent of the influence of contemporary investigations. The nearest fossiliferous limestones anywhere receiving mention are from thirty to fifty miles distant. A reference list of the literature relevant to these closest limestone occurrences as well as other geological and paleontological features is appended.

*This paper presented in abstract before the Ky. Acad. Sc., May 3, 1919.

The Type Locality.

The type fossiliferous outcrop of the Kendrick shale is one hundred and fifty yards above the yellow farm house (Kendrick homestead) on the headwaters of Cow Creek, Floyd County, Kentucky. The horizon which has been named the Kendrick shale for this outcrop, is a generally soft blue-gray calcareous shale carrying many calcareous and magnesium nodules.

Kendrick Fossil Bed.

This is the original fossil outcrop located on the headwaters of Cow Creek, just above Bear Branch, which forks just below the Dr. G. T. Kendrick house seen in the central background. The view is down stream and to the northwest. Photo by W. R. Jillson, April 6, 1919.

These nodules, which fall into two classifications, (1) hard, compact, and smoke gray; and (2) soft, easily disintegrated and neutral gray, may or may not carry fossils. The second or a budding-cone structure (Fig. 1). Chemical analyses of these formative characteristic of what may be called a cone-in-cone or a budding-cone structure (Fig. 1). Chemical analysis of these two types of nodules have been made under the direction of Dr. A. M. Peter, State Chemist, and are presented herewith:

(1) Hard, Compact, Smoke Gray Nodule—Lab. No. G-3842.

Moisture	0.37
Ignition	34.52
Silica	12.94
Ferric Oxide	2.64
Alumina	4.96
Titanium dioxid	.36
Calcium oxid	36.28
Magnesium oxid	4.89
Potassium oxid	1.34
Sodium oxid	0.16
Total	98.46
Calcium carbonate equivalent to the CaO	64.75
Magnesium carbonate equivalent to the MgO	10.16
Manganese and phosphorus	trace
Zinc	present
Sulphur of sulphids	present

(2) Soft, Neutral Gray, Cone-In-Cone Nodule—Lab. No. G-3843.

Moisture	0.42
Ignition	35.62
Silica	12.34
Ferric oxid	1.20
Alumina	4.66
Titanium dioxid	.40
Calcium oxid	41.30
Magnesium oxid	1.03
Potassium oxid	1.29
Sodium oxid	0.21
Total	98.47
Calcium carbonate equivalent to the CoO	73.71
Magnesium carbonate equivalent to the MgO	2.15
Manganese and phosphorus	trace
Zinc	present
Sulphur of sulphids	present

The iron in both samples is in the ferrous condition, probably mainly carbonate, with some pyrite.

Besides their inclusions in the nodules, the fossils are distributed generally through this limestone-shale horizon, but are rarely preserved as well outside as within the nodular formations. Although more than ninety per cent of the collections

"Cone-in-Cone" Nodule.

The radical distribution of the "Cone-in-Cone" "growth ripples" is well shown in this photograph of a calcarerous nodule taken from the Kendrick shale of the coal measures of Eastern Kentucky. The locality of occurrence is the Dr. G. T. Kendrick farm, Cow Creek, Floyd County, Kentucky. Collected and photographed by author, April 6, 1919.

have been secured from the above described type exposure, a few have been taken from two adjoining places on a continuous outcrop of the same calcareous shale bed. One of these is at the mouth of Bear Branch and the other a hundred yards below Bear Branch on the main Cow Creek. All three of these localities (and these are the only ones now locally known) may be placed within a circle having a diameter of 250 yards. At no place on the outcrop of the fossiliferous horizon are the fossils prolific in number or found in a typically good limy state of preservation. This is probably largely due to the robbing by the shale itself of a part of the original calcareous content of the embedded shells, and not, as has often been inferred, entirely to the exceptional paucity of lime in the shell of the living organisms. As a result of this condition these fossils are never secured without considerable difficulty, due to their marked tendency to crumble under the slightest pressure or strain.

The Kendrick shale lies about one hundred and seventy feet above the well known Prestonsburg, Miller's Creek, or Van

Lear coal, which is at this point that distance below drainage. It is directly underlain by two feet of blue sandy and calcareous shale. This shale is slightly fossiliferous, principally as casts. Following exposure, this shale breaks into semi-rectangular blocks about two feet square, and these upon further weathering, disintegrate into a typical blue marl—which was undoubtedly the original character of the deposit prior to consolidation. Later this marly shale may come to be shown to have a close faunal relation to the overlying Kendrick limestone—shale, but the two will probably never be considered as a single faunal unit, since the conditions of attending sedimentation is interpreted from the greatly differing lithology of the two formations, must necessarily preclude such a construction.

The Kendrick shale is directly overlain by about fifteen to twenty feet of massive and somewhat cross bedded sandstone which projects in this vicinity as an irregularly weathered cliff or ledge. Overlying this sandstone and about thirty feet above the fossil bearing horizon lies a thirty inch coal seam which for lack of more definite determination may be called the Kendrick coal, as it outcrops and is worked for domestic consumption on the J. C. Kendrick farm. Whether this coal is the same as the "Whitesburg" coal or the same coal as that which is called the No. 2 seam at Prestonsburg is not known. Certainly it is the next and only coal of commercial importance here above the Prestonsburg coal which in this locality goes under drainage on Cow Creek a short distance about its junction with the Levisa Fork of the Big Sandy River.

Invertebrate Record.

From a collection of several hundred invertebrate fossil specimens, taken from this locality and submitted to him for comparison, Professor Charles Schuchert, Curator of the Peabody Museum, has submitted the following tentative list of identifications:

Corals—Number of Species, 1.

Lophophyllum proliferum (index.)*

Crinoids—Number of species, 1.

Basal plates of a calyx—Undetermined.

Brachiopods—Number of species, 7. All rare

Glossina nebraskensis.
Orbiculoides convexa.
Orbiculoides manhattensis.
Productus cora—small.
Spirifer rockymontanus (index.)
Spirifer cameratus (index.)
Seminula subtilita.

Pelecypods—Number of species, 11.

Nuculana bellioetriata.
Nuculana, species undetermined—rare
Nucula ventricosa (index.)
Clinopistha radiata.
Schizodus, species undetermined.
Solenonga, species undetermined. A.
Solenonga, species undetermined. B.
Modiola subelliptica.
Astarella, species undetermined (index.)
Allorisma, species undetermined (index.)
Aviculopecten, species.

Gastropods—Number of species, 11. Six rare.

Bellerophon, species undetermined (index.)
Patellostium, species undetermined.
Pleurotomaria, cf. Larii—rare.
Pleurotomaria, species rare. 3 specimens.
Pleurotomaria tabulata. Rare. (index.)
Pleurotomaria depressa.
Soleniscus medialis.
Soleniscus gracilis—rare.
Soleniscus texanus—rare.
Polyphemopsis peracuta—rare (index.)
Zygopleura nodosa—rare.

Cephalopods—Number of species, 7. Two rare

Orthoceras rushensis.
Orthoceras, species undetermined.
Orthoceras, species undetermined—rare.
Nautilus, species undetermined—rare.
Nautilus, species undetermined—rare
Goniatites, species undetermined.
Goniatites, species undetermined.

*These indexes refer to Pennsylvanian System.—W. R. J.

Faunal Characteristics.

A review of the above incomplete determinations shows there are now at least thirty-eight separate species present in the Kendrick limestone-shale horizon. Further work may reasonably be expected to show not less than a total of forty-five and possibly fifty different forms. Of these about ten are new species, and between sixteen and twenty are rare in the coal measures as now understood in Eastern North America. Moreover the entire collection is new to Kentucky, no paleontologic work ever having been done before in this horizon.

The Kendrick fauna is clearly early Pennsylvanian—that is, Pottsville. This is shown by the presence of the Brachiopod, Spirifer rockymontanus. Knowledge of the local stratigraphy suggests that the Kendrick fossil horizon should be placed in the lower part of the Wise formation or Upper Pottsville, with the Norton formation just below it corresponding to the middle, and the Lee formation further below it correlating with the earliest Pottsville sediments.

Altogether the Kendrick fauna is a peculiar Pennsylvanian one, a condition which in all probability is due to the clear exhibition of mud facies. Brachiopods usually so common in the Coal Measures are here rare. On the other hand practically all the common guides are absent. Mollusca are revealed as the common fossils and all appear to be mud lovers to some extent. The fauna is particularly interesting and unique because of the many specimens of Cephalodods, especially the Gonitites. These are usually very rare or entirely absent in the Appalachian Coal Measures. So far no trace of Trilobites, which are rare in the Pennsylvanian System, or of Fusilina, which are usually present, if not prolific in this system, has been found. These two groups, however, may possibly later exhibit representatives as a result of more intensive collecting work in the field.

Stratigraphic Interpretation—Conclusion.

In summation, then, the Kendrick fossil shale horizon, though lacking the safest or commonest Pennsylvanian index guides, presents the true Pennsylvanian characteristic of a cosmopolitan, long range fauna. Such a fauna necessarily lived under peculiar, shallow, semi-marine conditions. These condi-

tions may be truthfully represented as continuously changing and aggrading through rather rapid sedimentation into swamp land areas. The waters may hardly be considered as having been typically marine at any point even for a very short period. The widespread absence of marine fossils generally throughout the Coal Measures, and the extreme paucity of lime in the shells where they are found indicate the very trying environmental conditions presented to marine invertebrates endeavoring to migrate into these inconstant muddy Pottsville seas.

Along what line, whether broad or narrow, and from what local direction the Kendrick fauna progressed in its invasion of this Eastern Kentucky region may as yet only be inferred. It has been held by Girty and David White that the general Pottsvillian migration was from a west or southwesterly direction from a Central Gulf embayment which encroached rapidly east, west and north over the Mississippi River valley during and following the early Pottsville. These correlations which are stratigraphic and chiefly based upon White's floral determinations coupled with somewhat meager faunal data from Girty, may not hold, however, for each and every one of the several fossiliferous limestone horizons which are now known to exist in Eastern Kentucky. The character of the sediments of the Eastern Kentucky Pottsville indicates a certain and impassable barrier between this area and the marine Atlantic. Assuming that the fauna did come from the west, as there seems to be good reason to believe, it must have passed through the relatively shallow seas lying on or about the Cincinnati-Nashville arch which, if not a unit insular land area in this later Pottsville time, undoubtedly acted as a very definite barrier to the great majority of the invading species. The wonder that there is found any marine invertebrate life at all in this semi-isolated Pottsvillian pocket is further increased by a realization of the fact that these hardy pioneering faunas were continually subject to and repeatedly suffered from total extinction, when only partially established in their new environment through the rythmic grading up process of Pottsville sedimentation.

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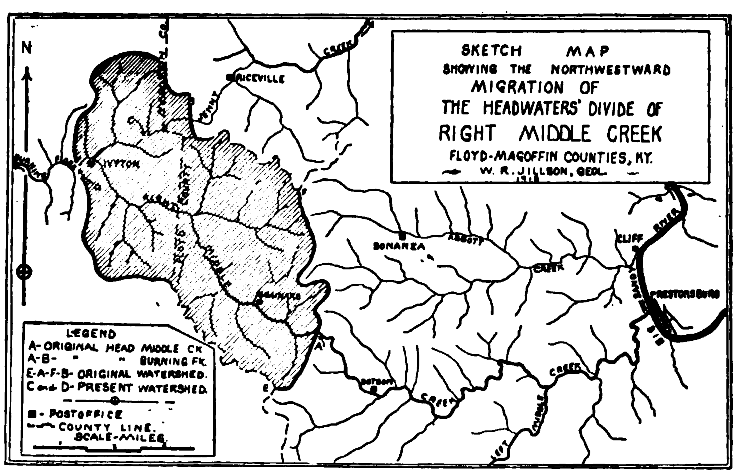
First Published July, 1919.

VI.

The Migration of the Headwaters Divide of Right Middle Creek, Floyd County, Kentucky.*

The headwaters divides of many streams rising in the foothills of the Appalachian mountains have experienced horizontal shifting of migration. That such movements have taken place in the eastern part of the Cumberland plateau is apparent upon inspecting the Prestonsburg, Paintsville and Salyersville, Kentucky, topographic sheets, the first two of which have recently been issued by the United States Geological Survey. Middle Creek, in Floyd County, Kentucky, presents uncommonly plain evidence of migration, and the results of a study of the drainage basin of this stream are considered worthy of record.

As shown on the accompanying map Middle Creek is a large easterly flowing tributary of the Levisa Fork of the Big Sandy



River, which it joins at the town site of Prestonsburg. About 3 miles from its mouth Middle Creek branches and the Right Fork of Middle Creek, or, as it is locally called, Right Middle Creek, extends westward about 14 miles.

*Am. Jour. Sc., Vol. XLVII, pp. 60-64, Jan., 1919.

The present watershed of the upper part of Right Middle Creek is indicated by the western, northern and eastern edges of the shaded area. The lower pass, or "gap," is found at a quarter of a mile west of Ivyton, Magoffin County, at D, and is about 960 feet above sea level. The "gap" is flat and swampy on the Burning Fork side; but on the Ivyton side it is perfectly drained, and erosive forces are active. At C, within the shaded area, is another low pass. These two passes indicate points of movement of the shifting divides. The upper part of Right Middle Creek basin is bounded on the west by the basin of the Burning Fork of Licking River, on the north by the basin of Jenny Creek, a tributary of the Levisa Fork of the Big Sandy River, on the east by the basin of Abbott Creek, which is also tributary to the Big Sandy River.

From a combined study of the field geology, the drainage courses and the topography, it is apparent that Right Middle Creek has shifted its divide 8 to 10 miles northwestward and has captured the headwaters of the Burning Fork of Licking River. The extent of the captured area is about 20 square miles and is indicated on the map by the shaded area. Apparently the original head of Right Middle Creek was along the line E to A. Capture resulted from a gradual pushing to the northwest of the Right Middle Creek, Burning Fork "gap" from A to the present location at D. The Burning Fork, already somewhat entrenched when the shifting began, offered in its own main channel the lowest point for capture by the advancing headwaters of Right Middle Creek. As a result, today the upper portion of Right Middle Creek is superimposed upon the old channel and basin of the Burning Fork. Field evidence is as follows:

1. The tributary streams within the shaded area flow northwestward at an acute angle against the main current of Right Middle Creek.

2. The valley of the Burning Fork of Licking River is a broad, open, flat basin, with low rounded hills and imperfect headwater drainage. The Burning Fork itself is a very small stream and out of proportion to the size of its valley. Aggradation is in progress.

3. The valley of Right Middle Creek from Ivyton to a point one mile below Grainard presents the physiographical opposite

to the valley of the Burning Fork. The Right Middle Creek valley is V-shaped and in some places the walls of the creek are nearly vertical. There is scarcely any "bottom land," the hills are high and steep, and the drainage is perfect. Erosive forces are actively engaged.

4. Between Ivyton asnd Brainard, Right Middle Creek is bordered by imperfect terraces developed on a strong sandstone member of the Pottsville series, through which the Right Middle Fork has cut. Probably this sandstone formed at one time the floor of the headwaters of the Burning Fork which were too feeble to cut through it and meandered back and forth across it, carving out a wide, flat valley at a high elevation. Toward Brainard the terraces gradually become less distinct and finally disappear.

5. Within the shaded area the channel of Right Middle Creek is choked with gravel and bowlders. The stream is still degrading rapidly.

6. The topography of Middle Creek changes abruptly 1½ miles below Brainard. At A the valley broadens, the hills become lower, the wagon road comes up out of the creek to find bottom land on either side, and the stream meanders back and forth in a slightly aggraded valley floor of sandy loam.

7. From A to the mouth of the stream, all tributaries come into the main channel at an acute angle with the current. The hills have an older, round-off, and worn-down appearance, and the broadened, level, slightly aggraded floor indicates an excess of eroded material from the headwaters. No trace of terracing remains.

Migration has also taken place near the headwaters of Jenny Creek. From Riceville southwestward Jenny Creek has cut through a thick sandstone member of the Pottsville and has developed a box canyon known locally as "The Narrows Fork." By so doing Jenny Creek tapped and appropriated one of the minor tributaries of the former head of the Burning Fork of Licking River. This captured tributary is seen on the map just to the east of the "gap" at C within the shaded area. According to field observation the "gap" at C is now shifting very slowly as a balance in elevations of the headwaters of the two competing creeks has almost been reached. Jenny Creek carries about

the same amount of water as Right Middle Creek and has a lower average elevation. The question therefore arises: Why did not Jenny Creek capture the head tributaries of the Burnig Fork? The answer involves a consideration of local structures as given below.

1. *Difference in Elevation.* Right Middle Creek is a tributary of the Levisa Fork of the Big Sandy River. At its mouth, Middle Creek has an elevation of about 580 feet at low water. The elevation at the mouth of Burning Fork is about 880 feet at low water. This difference of 330 feet is slightly increased when a comparison is made, as between the headwater tributaries of the Licking River where they adjoin the tributaries of Right Middle Creek. It was this difference in elevation which gave the first "push" to the northwestward migration of the divide between Burning Fork and Right Middle Creek.

2. *Difference in Structure.* But equally as important as the difference in altitude of the main channels of these two competing drainage systems were the structural and lithological features of the area, which, perhaps, may be considered the real cause of the rapid shifting of the Middle Creek-Burning Fork divide. The slight difference in the structure and lithology also may explain why Jenny Creek, possessing the advantage of a somewhat lower stream channel could not overtake Right Middle Creek in the race for the headwaters of the Burning Fork.

The village of Ivyton is near the center of a region of local uplift—a structural dome. This dome sends off rather high limbs to the west, to the north, and to the southwest. A somewhat lower limb extends to the east, and it is up this limb that the headwaters of Jenny Creek progressed westward. But the lowest and steepest dipping limb extends to the southeast, almost in the course of Right Middle Creek, and there is a structural drop in this direction of over 100 feet in a very short distance. The strong sandstone member of the Pottsville series, through which both Right Middle Creek and Jenny Creek have had to cut, has a somewhat softer texture in the lower courses of Middle Creek than on Jenny Creek. In these two factors, then, all others being excluded, lies the key to the situation. Right Middle Creek, with a somewhat softer rock to cut and a much steeper structural limb to ascend, was more favorably situated than Jenny Creek, although Jenny Creek possessed the initial

advantage of a somewhat lower channel. Right Middle Creek, a veritable giant, has removed a mountain 10 miles long, has captured the headwaters of its indolent neighbor, the Burning Fork, and as a penalty for the theft must for the rest of geologic time run backwards and "uphill" throughout its upper course.

The migration of the Burning Fork divide, or "gap," is still in active progress, though it is probable that now having reached the top of Ivyton structure the rate of the recession will decrease materially. After progressing a little farther northwestward down the fixed course of the Burning Fork, the Right Middle Creek "gap" will soon come to a more or less stationary position, because the "gap" will have passed over the crest of the Ivyton structure, where the factor of reverse dip may be expected to operate negatively upon further northwestward recession. The influence of this reverse dip may reasonably become so strong as to counteract the positive forces still operating which favor migration and are still maintained by the difference in the initial surficial elevation of the waters of this locality which are tributary to the Big Sandy and Licking rivers.

Re-published July, 1919.

VII.

The Low Sulphur Coals of Kentucky.*

Within the last ten years Kentucky has become celebrated for its low sulphur bituminous coals. Prior to this time many practical investigators had already made this important discovery, but it remained unknown to the general public until the last extension of Kentucky's mountain railroads was completed. The coals of Kentucky are broadly separated into two geographic units—the Eastern and the Western coal fields. On a basis of their sulphur content these coal fields, however. really fall into three units. As indicated on the accompanying map (Fig. 1), these are designated by numbers, 1, 2 and 3. No. 1, the very southeastern part of the state, shows the lowest sulphur—all coals averaged. In this field the maximum is 1.04 and the minimum as low as .68—both averages and not individual analyses, which would of course show much greater variation. Included in this group are the following counties: Lawrence, .87; Martin, .75; Johnson, .73 Magoffin, .87; Floyd, .88 Pike, .68; Knott, 1.04; Perry, .77; Letcher, .80; Leslie, .70; Harlan, 79; Knox, .86; and Bell, .92. The total average sulphur content for these thirteen counties is 0.82.

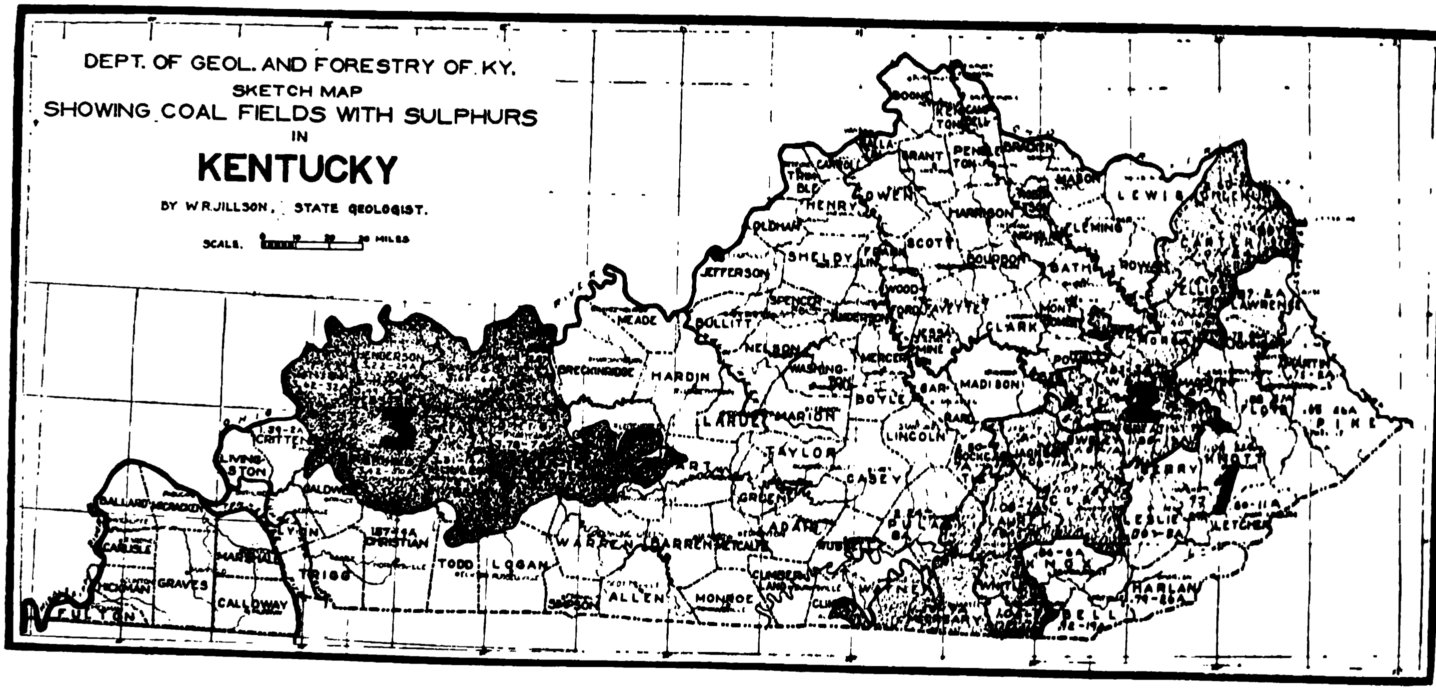
Bordering the restricted low sulphur field of Eastern Kentucky is the No. 2 belt (slightly darker), which is commonly known as the western border of the Eastern coal field. Here the maximum sulphur is 2.91 and the minimum 1.05. Again these are averages and not individual analyses. The counties in this group are: Greenup, 2.60; Boyd, 1.67; Carter, 1.7; Morgan, 1.40; Wolfe, 1.83; Lee, 2.93; Breathitt, 1.85; Owsley, 1.9; Jackson, 1.06; Rockcastle, 2.30; Clay, 109; Laurel, 1.08; Pulaski, 2.24; Whitley, 1.05; McCreary, 1.50; and Wayne. The sulphur percentage average for this No. 2 area, including fifteen important counties, is 1.65.

*Also in Bull. 1152, A. I. M. M. E., 1919.

In the Western Kentucky field the great increase in the percentage of sulphur is at once apparent. Ohio County with 3.78 is the highest and Hancock with 2.87 is the lowest. The percentages by counties are as follows: Hancock, 2.87; Henderson, 3.22; McLean, 3.27; Muhlenberg, 3.31; Hopkins, 3.42; Webster, 3.49; Butler, 3.50; Union, 3.62; Daviess, 3.65; Ohio, 3.78. The sulphur percentage average for the No. 3 area including ten counties and all of the Western Kentucky coal field is 3.41. In arriving at the above averages upon which the boundaries of the three districts were determined, 514 selected air dried analyses were used out of a total of about 750, which were reviewed. These analyses were made by two agencies, the U. S. Bureau of Mines and the Kentucky State Chemist. The number of analyses used per county may be found by referring to the map. Fig. 1, e. g. Floyd, 0.88—37 A., which is Floyd County percentage of sulphur 0.88 secured as an average from 37 analyses. In the following table of the important low sulphur coals of Eastern Kentucky access was had to over 250 additional analyses of the same character, out of which 160 were selected and used in compilation of the data presented below.

TENTATIVE SEQUENCE OF THE IMPORTANT COMMERCIAL COALS OF EASTERN KENTUCKY.

The following table is not intended to be considered in the light of a definite correlation. Work toward such a correlation is now under way, but final results have not yet been obtained. The arrangement given, however, is correct within broad lines and will serve the purposes of this paper. Many small coals have been omitted and a number herein given as separate coals will eventually be co-ordinated. The coals here listed are found only in sulphur districts numbers 1 and 2, as indicated on the map See Fig. 1.


DEPT. OF GEOL. AND FORESTRY OF KY.
SKETCH MAP
SHOWING COAL FIELDS WITH SULPHURS
IN
KENTUCKY
BY W.R.JILLSON, STATE GEOLOGIST.
SCALE.
MILES

ALLEGHANY.

Coals.

Stamper—Very High—Small Area.

Hilton—Very High—Small Area.

POTTSVILLE.

Wise—Kanawha—Upper Pottsville

Coals.

Hindman—High Splint—1.45 (2A-Perry Co.) .675 (2A-Letcher Co.)

Cornett (Cannel)—.59 (1A-Letcher Co.)

Francis

Flag—.906 (4A-Leslie Co.)—.80 (5A-Perry Co.)—.55 (1A-Letcher Co.) —.75 (1A-Letcher Co.)—.67 (11A-Letcher Co.)

Hazard—.80 (5A-Perry Co.)—1.28 (4A-Leslie-Knott Co.) .70 (1A-Letcher Co.)

Haddix—.816 (Breathitt and Perry Co.)—1.06 (1A-Letcher Co.)

Hamlin—.87—(1A-Letcher Co.)

Pardee—1.14—(1A-Letcher Co.)

Fire-Clay (McGuire cannel)—.69 (1A-Leslie Co.)

Fire Clay—Hyden (No. 4)—Lower Hignite—.87 (Perry Co.) .72 (10A-Perry Co.)—.765 (4A-Letcher Co.)—.413—(3A-Bell Co.)

Whitesburg—Mills (?)—1.318 (1A-Letcher Co.)—.79 (1A-Letcher Co.)

Amburgy—.613 (Leslie Co.)—.98—(1A-Letcher Co.)

Elkhorn-Taggart—Moss (?) (No. 3)—.58 (6A-Letcher and Knott Co.)—.654 (15A-Letcher Co.)—.971 (10A-Floyd Co.)

Howard—Ivel (No. 2.)

Van Lear—Prestonsburg—(No. 1—Millers Creek—.593 (10A-Johnson Co.)—.698 (17A-Floyd Co.) Av. at Van Lear .50.

Straight Creek—.902 (8A-Bell Co.)

Collier.

Blue Gem—.8766 (1A-Knox Co.)

Bacon Creek (Lower Blue Gem.)

Harlan—Shelby Gap—Lily (?)—.805 (2A-Letcher Co.)—.776—(12A-Harlan Co.)

Norton—New River—Middle Pottsville.

Imboden—1.33 (1A-Letcher Co.)

Many unimportant coals.

Dorchester.

Manchester—Wide variation between—.47 (Low) and 2.65 (High) (Clay Co.)

Lee—Pocahontas—Lower Pottsville.

Beattyville—2.33 (7A-Lee Co.) wide variation between—1.041 (Low) and 3.991 (High) (Lee Co.)

Many unimportant coals.

Although considerable stratigraphic work has been done on the Western Kentucky coals—Map No. 3 area—no attempt is made here to portray the sulphur characteristic of these coals, since the district is without what may be called a commercial low sulphur coal. It is interesting from a stratigraphical standpoint to note the result of the plotting of the sulphurs of the coals of Kentucky, especially since to date, the Pennsylvanian System in this state has never been mapped, except in outline. Within broad limits then it may be said that sulphur district No. 1 corresponds with the Wise-Kanawha or Upper Pottsville, which forms the main body of the Kentucky commercial coals. Sulphur district No. 2 corresponds roughly with the Norton-New River or Middle Pottsville, and the Lee-Pocahontas or Lower Pottsville. It is relatively of much less importance. Sulphur district No. 3—The Western Coal Field—is probably Middle and Lower Pottsville.

The summation of averages of these sulphur percentages shows quite as much of a difference between districts 2 and 3 as between 1 and 2. It must be concluded then, that great and striking differences of sedimentation attended not only each division of the Pottsville, but that within any one unit of Pottsville time due to geographic location and proximity of continental or insular masses the same variation in point of size probably existed. It may be significant to point out in this connection that lowest sulphured coals of Kentucky are found farthest removed from the principal Pottsville marine sea—the Lower Mississippi embayment. Progressing toward this typical marine sea from east to west, the Pottsville sulphurs rise rapidly, and after one crosses the shallow channeled area on and just west of the Cincinnati anticlinal barrier in Central Kentucky the maximum is reached. Here then in the certain westward movement of these Pottsville waters out of the long arm extending northeast into Pennsylvania, may lie the logical solution to the problem of the distribution of the low sulphur coals of this period.

First Published July, 1919.

VIII.

The New Oil and Gas Pools of Allen County.

Location and Topography.

Allen county, one of the "Pennyrile" counties of Kentucky, lies in the central southern part of the state, adjoining the Tennessee line. It is bounded by Warren and Barren counties on the north, Monroe on the east, Macon and Clay, of Tennessee, on the south, and Simpson, of Kentucky, on the west. The altitude of the surface of the county varies from 825 above sea level in the southeastern part of the county to about 500 along the lowest portion of the Big Barren River on its northwestern border. Allen county is essentially an imperfectly dissected gently northwestward sloping table land in which the topography while certainly not excessively rugged is rough enough to cause a constant change in the scenery in every direction. The relief

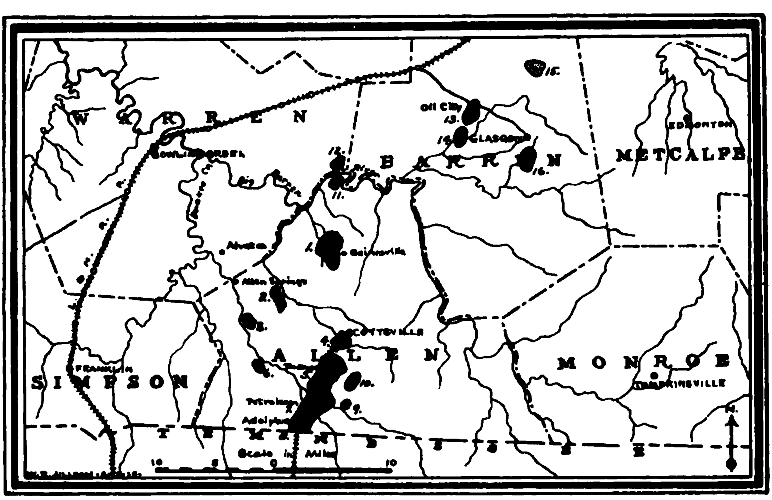


Fig. 1.

Sketch Map Allen and Adjoining Counties.

As shown above the principal Oil and Gas Pools of Allen County are: 1. Gainesville; 2. Bays Fork; 3. Butlersville; 4. Scottsville; 5. Rodemer; 6. Trammel Creek; 7. Petroleum; 8. Adolphus; 9. Rough Creek; 10. East Rodemer; 11. Jewell; and, 12. Moulder

varies from 150 to 300 feet. The main roads of the county are located on the rounded ridges to avoid the imperfect drainage of a large number of the sink holes which in various parts, especially the northwestern, are well developed in the soluble surface Mississippi limetone. There is approximately 400 square miles within the county borders. Scottsville—see Map, Fig. I—is the county seat. The drainage is that of the Big Barren River and its tributaries of these Trammel Creek and Bays Fork are the largest.

ACKNOWLEDGMENTS.

The data herewith presented represent a combination of such information as could be gleaned from the publications of the former Geological Surveys of Kentucky, together with many personal notes collected by the writer during various visits to Allen county prior to the spring of 1919. In March, 1919, the writer spent ten days in Allen, Warren and Barren counties, and it is upon this general reconnoissance that this paper is chiefly based. The oil and gas development in this portion of Kentucky is now going forward so rapidly—twenty-two completions were reported for the week ending May 31—that it is quite impossible to present any report that is thoroughly up-to-date. However, standing within the limit of reason, it is the purpose in offering this paper to advance the main facts of the geology of the oil and gas of Allen county leaving the wealth of attending detail to a more comprehensive report. Thanks are due to Mr. C. A. Phelps and Dr. E. R. Riggs, Mr. J. C. Kirby, Mr. W. H. Giltner and many other oil men in and about Bowling Green, Scottsville and Glasgow, for their many helpful suggestions and assistance.

STRATIGRAPHIC GEOLOGY.

The principal surface rocks in Allen County belong to the Mississippian System or Sub-carboniferous. They are chiefly limestones, St. Louis—the Big Lime of drillers—in the western part, and the underlying formations, Warsaw, Keokuk, and Burlington in the central and eastern part. Small areas of the Devonian Black Shale and Onondaga (Corniferous) Limestone have been exposed along the Big Barren River on the north-

east border and a few of the main creeks, especially Trammel, in the central southern section. Underlying the Onondaga (Corniferous) Limestone and occurring as very restricted outcrops due to stream erosion there may be found some patches of the limestone and shales of the Niagran group, which belong to the Upper Silurian. As in Allen County, the principal surficial rocks of the counties adjoining are Mississippian. It is a matter of twenty-five miles to the border of the western coal field and double that to the first Pennsylvanian rocks in the east. While there is a river valley outcrop of Ordovician rocks along the

Site of the Big Oil Tank Fire.
Burned area on Johnson farm on Difficult Creek, new Gainesville Pool, Allen Couty, Ky Note charred tank bases at right and dead trees in foreground. Photo by W. R. Jillson, Mar. 19, 1919.

Cumberland fifteen to twenty miles to the east, the real Kentucky Blue Grass is distant by 55 miles in an air line to the northeast, and the corresponding area surrounding Nashville in Tennessee is fifteen to twenty-five miles away to the southwest. The real reason for this distribution of the surface rocks is found in the major structural features of the region. Allen County lies on the western limb of the great Cincinnati Anticline, almost in the saddle between the Lexington and Nashville domes,* It is situated, however, slightly more upon the Nashville dome than otherwise, and for this reason the strata in this section find their normal dip to the northwest. The simplicity of this ar-

rangement may be readily seen by reference to Plate I, the Geologic map of Kentucky. Allen County lies just north of the dot in the state line under the first "E" in Burkesville. A generalized section of the exposed and unexposed rocks and the oil sands of the Allen County section is as follows:

MIDDLE PALEOZOIC SERIES IN ALLEN COUNTY AND CORRESPONDING OIL SANDS

System.	Series	Producing Sands	Notes.	
Mississippian	Warsaw		Exposed—not a producer	Limestones
	Fort Payne	Beaver Sand	Exposed partly Possible producer	Limestone
Devonian	Chattanooga	Stray Sands	Occasionally gas	Black Shale
	Onondaga	Gainesville Corniferous	The principal oil and gas producing horizons in Allen county and vicinity.	Cavernous Limestone
Silurian	Niagara	Rodemer Boyds Creek Scottsville		Sandy, impure Limestones
	Clinton	Deep Sands	Occasional producer.	Limestones and Shales
Ordovician	Cincinnatian	Upper Sunnybook Deep sand.	Very occasional producer.	Mostly Limetones
	Mohawkian	Trenton Deep sands.	Very occasional producer.	Mostly Limestones

The Producing "Oil Sands."

There are a number of oil and gas producing formations with their included "sands" in Allen County, but the principal amount of the oil production may be narrowed down and referred to two—the Onondaga or "Corniferous" of the Devonian, and the Niagaran of the underlying Silurian. It is estimated that ninety-five per cent of the production of this section is now being recovered from these two horizons and the indication is plain that these two horizons will continue to be the important ones of the future. Above the Onondaga or Corniferous the amount of either oil or gas production from the uncommon "stray sand" of the Black Shale is trivial. There is perhaps a very small amount of what is known as "Amber oil" production that may be referred to the lower part of the Waverly in a few unimportant isolated wells in Barren County. The total amount of all of this production is hardly worth considering from a commercial standpoint. Below the Niagaran the production again rapidly dwindles—for two reasons. One of these is that very few deep wells have been drilled in this section and

the other is that practically all of the deep wells have been dry, Evidently the production is not present in the deeper "sands" in any except in occasional instances.

The Onondaga (Corniferous) and the Niagaran are the formations upon which the attention of all oil men is justly focused. The situation with respect to these two "sands" even today with all the study they have received is one that still lacks a great deal of being clear. A number of obvious facts cause this. Field observations have determined definitely that a rather large unconformity occurs not only at the top of the Niagaran but also at the top of the Onondaga (Corniferous). This break has been observed by the writer to be so extensive in places that the entire Onondaga has been removed and what is considered the Niagaran or Upper Silurian was found to be resting unconformably directly beneath the Black Shale of the Devonian. The result of this has been to introduce a large element of uncertainty into the establishment of the production horizon in practically all wild cat wells. The first production, however, comes generally just below the Black Shale and may or may not be followed at from 50 to 150 feet deeper by a second or third pay.

NATURE OF THE "PAY SANDS."

While it is not easy to accurately and quickly determine whether the producing sand of any well is Onondagan or Niagaran, practice and the microscopic study of the drillings will tell much. From all observations it appears that the Onondaga (Corniferous) limestone of this section—generally unfossiliferous—is a true limestone, which is slightly to considerably cavernous due to solution. The cavernous characteristic is not a general or regular occurrence, but apparently is widely distributed as a local condition. What is regarded as the true Onondaga is dark and pitted on exposure but is gray with a brown tinge upon fresher surfaces. A comparison of a number of well records indicates that it may vary (probably due to its unconformable upper surface) from 5 to 50 feet in thickness. In some cases it may exceed this amount, but there exists some quetion in these instances as to the exact base of the formation, and it may be that in certain of these instances the bit had already pierced the underlying Niagaran lines. The absence of the

Onondaga in some places and its apparent tendency to thin down in many others seem to indicate that it might always be safer to assign less thickness rather than greater ones to it.

Though the Onondaga is sometimes absent, and the Niagaran is alway present, it is a fact that the latter sediments are much more difficult to determine than the former. Generally it seems that Silurian has a much higher fossil characteristic than the overlying Onondaga. But this does not help in the well records—when they are to be studied separately from the drill-

The Spectacular Johnson No. 2 Well.

This well at the time it was drilled in probably attracted more attention than any other in the new Gainesville Pool, Allen County, Ky. It is reported to have flowed 1,300 barrels in the first 32 hours. At the time this picture was taken it was still flowing. Photo by W. R. Jillson, Mar. 19, 1919.

ings. When the drilling sample sands are at hand the matter is somewhat simplified in so far as lithology goes, for the Silurian will quite usually present the notable characteristic of sandy—real sand grains—lime body. This seems to be the case also to a greater degree toward the top of the Niagaran than lower down. If closely compared with drillings from the Onondaga (Corniferous) the Niagaran drillings will be seen to be really quite different. And it is a fact at no place does the Onondaga exhibit the real siliceous sand grain.

Conclusions then must place the Niagaran as the better of the two formations from an oil reservoiring standpoint. Perhaps

this statement would not be without dispute if a generally more widespread porous or cavernous condition had been tested out and found to be existent in Allen County. It has been the experience of many producers and almost innumerable instances could be cited where the tightness of the Onondaga apparently was the only cause of a dry hole offsetting production. Due to the characteristics of changing porosity—which the bit alone can determine—drilleres in Allen County failing to secure production have found it a good rule to continue their drilling to salt water or to at least 150 to 200 feet below the base of the Black Shale. Frequently by so doing a change in porosity has experience to date does not justify a general prospecting for been encountered and with the change—production. However, productive sands deeper than 200 feet below the Devonian Shale.

A comprehensive idea of the stratigraphy of the unexposed rocks and the depths to various oil and other horizons may best be secured from a study of a number of representative logs. These logs are presented by pools and are unaltered in figure from the original copy which is given in feet.

WELL RECORDS.

Gainesville Pool Map No. 1.

J. R. Johnson No. 1.	Thickness.	Depth.
Soil	7	7
Limestone	184	191
Black shale	47	238
Blue limestone	6	244
Lime sand	36	280

J. R. Johnson No. 2.		
Soil	5	5
Limestone	177	182
Black shale	45	227
Blue limestone	7	234
Lime sand	1	235

J. R. Johnson No. 3.		
Soil	6	6
Limestone	166	172
Black shale—Devonian	49	221
Blue limestone	71	292
Lime sand	4	296
Limestone	14	310

J. R. Johnson No. 4.	Thickness.	Depth.
Soil	6	6
Limestone	166	172
Black shale	42	214
Blue limestone	5	219
Lime sand	28	247
Limestone	7	254

J. R. Johnson No. 5.		
Soil	4	4
Limestone	234	243
Black shale	44	287
Blue limestone	5	292
Lime sand	60	352
Black limestone	94	446

J. R. Johnson No. 7.		
Soil	8	8
Limestone	234	242
Black shale	46	288
Blue limestone	5	293
Lime sand	83	376

J. R. Johnson No. 8.		
Soil	18	18
Limestone	254	272
Black shale	46	318
Blue limestone	6	324
Lime sand	57	381
Black limestone	70	451

J. R. Johnson No. 9.		
Soil	6	6
Limestone	265	271
Black shale	46	317
Blue limestone	5	322
Lime sand	13	335
Black limestone	75	410

J. R. Johnson No. 10.		
Soil	18	18
Limestone	268	286
Black shale	44	330
Blue limestone	5	335
Lime sand	15	350
Black limestone	50	400

Andy Smith No. 2.	Thickness.	Depth.
Limestone	274	274
Black shale	46	320
Blue limestone	19	339
Lime sand	30	369
Limestone	6	375

Andy Smith No. 3.		
Limestone	276	276
Black shale	50	326
Blue limestone	23	349
Blue limestone	12	361
Lime sand	31	392
Limestone	4	396

Scottsville Oil Pool, Map No. 4.

Ocala Oil Co. No. 4.

Frost Farm, 3 Miles S. of Scottsville.

Top of black shale at	(Devonian)	210
Base of black shale at	(Devonian)	257
First oil show at		271
Oil		282
Botton of well at		287

Ocala Oil Co. No. 5.

Top of black shale at	(Devonian)	223
Base of black shale at	(Devonian)	269
Frist pay at		294
Salt water at		308

Ocala Oil Co. No. 6.

Top of black shale at	(Devonian)	209
Base of black shale at	(Devonian)	283
Oil and water at		283
Oil at		298

Rodemer Pool, Map No. 5.

Keen Well No. 7.		
Lime and shale	120	120
Black shale (Devonian)	43	163
Blue lime	11	174
Brown sand (lime?)	3	177
Light lime	6	183
Brown sand (lime?) Pay sand	9	192
Hard lime	2	194
Light blue lime	9	203
Dark lime	2	205
Gray lime	1	206
Dark lime	6	212
Blue lime	10	222
Light-blue lime	3	225

Rosa Holder Farm.	Thickness.	Depth.
Soil	28	28
White lime	158	186
Black shale (Devonian)	41	227
Lime-Gas show at 245. Water at 320	98	325

Settles Well No. 3.		
Casing	81	81
Limestone	119	200
Green shale	3	203
Black shale (Devonian)	45	248
Dark lime (Oil smell)	5	253
Hard lime	10	263
Brown oil-sand (lime?) Gas	13	276
Oil show at		276
Shaly lime	14	290
Dark brown sand (lime?) Oil show	5	295
Hard blue lime	6	301
Sandy lime—Oil show	7	308
Hard blue and shaly lime	20	328
Hard sand (?)	1	329
Salt water	5	334

Trammel Creek Pool, Map No. 6.

Well on Big Trammel Creek.

Five Miles Southwest of Scottsville.

Soil	12	12
Blue limestone	90	102
Black shale (Devonian)	13	115
Black rock—Oil at 127	12	127
Blue limestone	40	167
White sand (lime?)	20	187
Black rock—Gas at 193	6	193
Soft sand rock (lime?)	10	203
Yellow flinty sand (lime?) Salt water	2	205
"Trenton" rock*	600	805
Blue limestone	200	1,005
"Trenton" (light)	85	1,090

*"Trenton" is driller's distinction.

Petroleum Pool, Map No. 7.

Well at Petroleum.

Soil	10	10
Blue limestone	30	40
Black shale (Devonian)	9	49
Light gray sandstone (lime?) Oil at 132	83	132

Adolphus Pool, Map No. 8.

J. H. Carter Farm, Northeast of Adolphus

		Thickness.		Depth.
Top of black shale (Devonian)	at			152
Base of black shale (Devonian)	at			195
Sulphur water	at			196
Oil sand (lime?)	at			200
Lime	at			221
Sand (lime?)	at			225
Blue clay	at			253
Sand (lime?)	at			257
Slate	at			271
Lime	at	281	to	823
Sand (?)	at	823	to	899

Widow Lane Farm, Near Tennessee Line.

	Thickness	Depth
Soil	5	5
Lime	65	70
Sand	20	90
Blue lime	40	130
Slate	5	135
Sand	10	145
Slate	5	150
Black shale (Devonian)	55	205
Gray lime	30	235
Oil-sand (lime?)	10	245
Blue lime	20	265
White lime	3	268

Well was dry.

Various Locations.

George Jewel Well.

	Thickness	Depth
Soil and limestone	193	193
Black shale	50	243
Blue limestone	7	250
Lime sand	28	278
Broken limestone	14	292
Lime sand	4	296

Wood Jewell Well.

	Thickness	Depth
Soil and limestone	188	188
Black shale	50	238
Blue limestone	2	240
Lime sand	10	250

T. Y. Oliver Well No. 1	Thickness.	Depth.
Soil	37	37
Limestone	274	311
Black shale	43	354
Lime sand	65	419
1st sand 5 ft.		
2nd sand 10 ft.		
3rd sand 14 ft.		

B. T. Williams Well.

Soil	30	30
Limestone	272	302
Black shale	48	350
Lime sand	98	448
Slate	54	502

L. W. Nichols Well No. 1.

Soil	13	13
Limestone	250	263
Black shale	57	320
Blue limestone	5	325
First sand	5	330
Blue limestone	12	342
Second sand	20	362
Limestone	20	382

Structural Geology.

As has been stated the normal dip of the strata underlying the Allen County section is to the northwest, and this fall will average about thirty feet to the mile. However, this dip is far from uniform and it is this lack of uniformity which is, in part at least, responsible for the accumulation in commercial quantities of the Allen County petroleum. The deviation from the normal dip to the northwest has resulted in producing in a roughly parallel arrangement a large number of small, somewhat localized minor folds, domings or terraces. The smaller folds or anticlines may generally be considered as lying with their major axis extending in a northeast and southwest direction. Roughly the progress of development has delimited two groups of these small fold which are extremely productive. See map, Fig. I. The Gainesville No. 1, Bays Fork No. 2, and Butlersville No. 3 pool may be considered the western group, with the Steffy

No. 14, Oil City No. 13, and Hiseville No. 15 pools, further to the northeast in Barren County a possible extension. The second group of pools and really the older of the two in point of development is the Scottsville No. 4, Rodemer No. 5, Petroleum No. 7, and Adolphus No. 8, Rough Creek No. 9, and East Rodemer No. 10, and possibly the old Oskamp No. 16 in Barren County, again a northeastward extension.

No attempt has been made as yet to map these separate structures, but it is planned to map some of them during the present field season. The work will be done on the sub-surface structure—that is the first oil pay. It is the writer's conclusions' based upon field obervations, that while many structural indications are to be found at the surface, none of them may be used to advantage in preparing a working map. The reason for this is found in the unreliability of the continuity of the sub-surface structure. It is definitely known for instance in the Gainesville pool that the structure of the surface worked on a thin key bed in the shale is not exactly true to that of the oil pay which is developed into at least two rather restricted domes. However, prior to any large amount of drilling in a given locality, surface structure is all that one may go by and should not be discounted where the absence of a soil mantel makes it possible to use it.

It is not intended that the reader shall infer that these two above outlined lines of minor folding are the only ones and that production will be confined to them. On the contrary the writer believes that there is very good evidence now developing which will go to show that another line of these producing structures will be brought in somewhat along the Warren County line from the Big Barren River southwestward into the eastern part of Simpson County. Furthermore these conditions may well persist to the east and extend not only over the Long Creek section but across the Allen line into Monroe County.

Structure vs. Porosity.

Any discussion of an oil field in Kentucky and especially the shallow limestone fields would be thoroughly inadequate that did not make some attempt at least to portray the real condition existent as regards porosity. In these oil fields either Appalachian, Mid-Continent or elsewhere that produce petroleum

from genuine silicious sandstones—porosity does not enter as quite as vital an issue, since all sands are more or less porous. However, when the producing horizon is known to be a limestone, porosity becomes at the same time a very important thing, for most limestones that are protected from surface exposure or rapid water percolation are or should be "tight." The "loose" or porous cavernous limestone then is not the rule, but rather the exception at protracted depths below the surface. The term protected here means something more than simply out of sight too. It implies an essentially impervious cap rock of some description. In Allen County this protecting cap rock is of course the Devonian Black Shale.

Reference has already been made to the cavernous condition of the Onondaga limestone, and the sandy phase of the impure limes of the upper part of the Niagaran has also been pointed out. It is the writer's opinion that the Onondaga (Corniferous) where "loose" forms an almost ideal oil "sand" reservoir. It is hard to see, with large interlocking interspaces, such as this limestone frequently shows, how a much better reservoiring medium could be designed. However, the great fault with Onondaga (Corniferous) porosity is not with the porosity at all, but with the amount and the irregularity of it. There seems to be no guiding rule to go by and as has been instanced splendid producers have been offset on location again and again with absolutely dry holes due simply to a sudden tightening or compacting of the limestone. The result of this characteristic has been to prematurely condemn much territory that may eventually be redrilled to pay. Due to its irregularity in porosity therefore the Onondaga cannot be said to be quite as good a reservoiring "sand" as the actually sandy limes and associated beds of the Niagaran. These sands present a truly sandy phase and the knowledge of this fact should always—unless oceans of waters are met—encourage the prospecting driller to test them out.

In summation then the outstanding facts as revealed by the actual development are that structure—anticlines, terraces, etc. —certainly control the accumulation of petroleum in Allen County. But porosity is a vital feature and any anticline that has no porous bed developed within it below the Devonian Black

Shale may be looked upon as a failure. Petroleum can not and does not accumulate under very "tight" sand structures. Water conditions, however, being generally present serve always to segregate the petroleum in all porous places, and where tightening "sands" on the flanks of structures have prevented the upward climb of the petroleum it is conceivable that it should collect at some lower—possibly even the lowest—structural point. Thus it is logically conceivable in the peculiar limestone that the petroleum may be synclinal even in the face of ample water pressure and adequate structure. Of course this is a condition that could not possibly obtain in a true siliceous sand. But it is nevertheless a not uncommon occurrence in Allen County and it is confidently expected that structural mapping in this section will show some synclinal production.

The theoretical development of the actual cause of the cavernous or porous condition of the Onondaga may not be attempted in this brief paper, but the suggestion may not be out of place that temporary subaerial conditions of leeching in post Onondaga times may have been quite as responsible for this porous condition, as the same conditions are well known to be now in many other limestones. This view is strengthened by the knowledge of the unconformity and disconformity above the Niagaran and the base of the Black Shale. Conditions favorable to rather rapid solution of the hardly consolidated young Onondaga were certainly existent. This viewpoint is substantiated by the fact that the Onondaga is frequently cut down to a very thin remnant and is in a few places at least entirely removed.

SOURCES OF ALLEN COUNTY PETROLEUM.

Much has been said on the subject of the ultimate origin of petroliferous hydrocarbons and the end of the discussion is not yet in sight. Many statements have been made that had better never been advanced. Literature on this subject is rich in theories and original ideas but poor indeed in actual proof. However, some certain progres has been attained and the minds of most professional oil and gas geologists have become clarified and united in support of—in the great majority of instances—an original organic source for petroleum and natural gas. Ac-

cording to some it is animal, according to others vegetable, but the rank and file take the more reasonable middle course and ascribe both plant and animal origin.

Assuming then in consensus with the general professional opinion the organic source of petroleum—it really could not be otherwise in the undisturbed sediments of Allen County—the decision does not settle the matter, but on the contrary provokes the question as to the original hydrocarbon bearing formation or group or rocks. And here it is that the writer believes that many who have interested themselves in this subject, and subscribed their approval to the Devonian Black Shale as the indigenous source of the principal amount of Kentucky petroleum. are in error. Plainly, the writer has no sympathy with this view or the fallacious philosophic conceptions which are put forth to uphold it.

It may not be too plain a statement to say that apparently the reason why Kentucky's petroleum---always speaking of the major portion generally found just beneath the Black Shale—is ascribed in indigenous origin to the Devonian Black or Chattanooga Shale, may be found in the fact that such reasoning follows the line of least resistance. The Devonian Shale is a very carbonaceous formation. It will burn under some conditions spontaneously* and always ignite with a little kindling. The writer has many times distilled both oil and gas from the shale. The oil—a tarry substance—may be produced, when normally severe destructive distillation tests are imposed upon the shale at the rate of between twenty and thirty gallon to the ton.** While this is not really as high as the run of some of the celebrated Colorado† and Utah petroliferous shales which it has been stated reach as high as fifty and even eighty gallons to the ton, it is nevertheless a very highly petroliferous condition, and very much higher than the average shale.

However, it does not follow that because a rich oil bearing, chiefly limestone series is overlain by a very unusually rich carbonaceous shale of considerable thickness that this lime series must or probably did secure its oil from that shale. Such an

*An interesting case of spontaneous combustion—P. C. Bowers. Resources of Tenn.: Vol. VI, No. 1. Paper No. 3, pp. 37-40, Tenn. Geol. Surv., Jan. 1919.

**Author's unpublished experimental notes.

†Oil shale in Northwetern Colorado and adjacent areas. D. E. Winchester. U. S. G. S. Bull. 641. F.

assumption might and probably does hold good in a section where shale and sands alternate with small limes but the conditions in Kentucky are special and an inquiry into them disallows the above conception. The proofs which may be considered both positive and negative are as follows:

In the state of Kentucky: (1) The petroleum recovered below the base of the Devonian Black Shale exhibits a wide chemical variation indicating varying conditions of ultimate source. A Black Shale group of petroleum might be expected to show uniformity comparable to their source. (2) The petroleum is generally found one or more "pays" beneath a very compact rock at the top of the lime series, which it is believed would have held any migratory gravity inspired petroleums above it much more easily than it now holds them below under water pressure. (3) The Black Shale directly overlies the lime under its cap. Under no conditions, except that of absolute dryness, could the therein contained petroleums have moved downward through the hard cap rock and into the cavernous limestone beneath. It cannot be shown that the Black Shale has ever been drier than it is at present, if as dry. (4) Slight moisture would certainly have nullified the gravitative force, and capillarity would reasonably in any event have been a strong retaining factor against downward movement of petroleum. With any considerable degree of water present it is hardly conceivable according to physical laws of differential gravity how the isolated petroleums (if indeed they were isolated and free to move) could have done other than move slowly upwards.* At higher levels they would have been trapped by the overlying shales, limes and sands of the Waverly group. (5) Assuming that some part of the Black Shale hydrocarbons in some as yet unexplained way got down into the underlying limestone, it would be a very much one-sided arrangement if an equal amount did not in some locality at least move upward according to natural laws and find lodgment in the fine reservoiring strata toward the base of the Waverly. Yet the large amount of drilling in Kentucky has not demonstrated this to be the case. (6) Assuming that the larger part of the indigenous Black shale petroleums have been free to move (never been

*The Role and Fate of the Connate Water in Oil and Gas Sands. R. H. Johnson, Am. Inst. Min. Engr. Trans., Vol. 51, pp. 587-610, 1916.

shown to be a fact) it would only be safe to infer that any stray sand lenses in the shale would be very highly impregnated with oil containing dissolved gas. Sand lenses in the Black Shale are not common but they do occur in Kentucky. And experience has shown that where they do, these sands are always gassy and never commercially petroliferous at all. This well known condition apparently precludes a further tolerance of the groundless theory of the Black Shale source.

Many other arguments quite as logical and destructive could be brought to bear on this subject, but the limits of this paper will not allow of their detailed presentation. Suffice it to say that the writer feels there is ample proof at hand to demonstrate that the Kentucky crude petroleum recovered from below the Devonian Black Shale is a strictly lime and shale oil derived indigenously from the Onondaga (Corniferous) and underlying Niagaran and possibly lower formations. As such it is probably of varying original animal and vegetable constituency, which readily accounts for the great variation in the bacterial sulphur component of analyses of samples from producing wells located within the same field and producing from the same horizon or horizons. Furthermore in the light of existing field conditions taught by the drill it seems unnecessary to suppose that any considerable amount of the Black Shale hydrocarbons have ever been freed for migration. It seems much more reasonable (since they may now be recovered at the rate of from twenty to twenty-five gallons to the ton) to consider them all still locked within the shale awaiting the day when they shall be released through mechanical means as a great reserved mineral oil resource.

PRESENT DEVELOPMENT AND FUTURITY.

Beginning with a single producing oil well on Bays Fork* considerably less than a hundred feet deep and drilled shortly after the close of the Civil War, probably in 1865 or 1866. Allen County has come to the front rank as an oil producer in Kentucky. Today it is probably only exceeded by Lee County in point of actual production. A number of factors have favored this turn of affairs. Firstly, Allen County is easy of access—

*Note on the Geological Position of Petroleum Reservoirs in Southern Kentucky and Tennessee. Am. Jour. Sc., 2d Series, Vol. 42, pp. 104-107, 1866.

that is as compared to the other mountain counties. Secondly, the drilling fortunately is shallow—generally less than 350 feet —and therefore dry holes are less expensive and hazardous to the prospector of limited means. Thirdly, production has been secured in very commensurate proportions to the amount of drilling done. It is this third point that has really made Allen County a success. Fourthly, commercial outlet for the Allen County oil has been practically maintained from the first, which has quickened field activity.

The preent season is witnessing the zenith of Allen County development. There are at present at least 200 rigs at work in this county and more will be on the ground before the end of the summer. Weekly completions are steadily increasing and with them the amount of production. Two short pipe lines—both of which have recently become inadequate to move the crude—serve the Allen County fields. These are the American Pipe Line Company (2-inch), Gainesville Pool to Bowling Green, and the Indian Refining Company Pipe Line (4-inch) from the Gainesville Pool to Scottsville. Both of these lines end at tank car station on the Louisville & Nashville Railroad. The Rodemer, Petrôleum and Adolphus pools feed directly to gathering lines of the Indian Refining Company with outlet at Rodemer, Kentucky.

The tank car shipment totals of the Indian Refining Company in Allen County for the years 1915 to 1919 are as follows:

Tank Car, Allen County Crude.

Year.	Barrels.
1915	191.26
1916	27,616.23
1917	31,936.94
1918	20,990.86
1919 (2½ months)	1,774.57
Total barrels	82,509.86

The pipe line run of the Indian Refining Company in Allen County during the year 1918 and January and February and half of March, 1919, is as follows:

Pipe Line Runs, Allen County Crude.

Year	Scottsville.	Rodemer.	Total.
1918	28,233.25	9,886.63	38,119.88
1919 (2½ mo.)	38,455.56	17,906.71	56,362.27
Total barrels			94,482.15

The total amount of crude taken out of Allen County by the Indian Refining Company from 1915 up to March 16, 1919, would be the sum of the above totals or 176,992.01 barrels.

In addition to the above figures there is an increasingly large amount of crude oil from the Scottsville, Rodemer, Petroleum and Adolphus pools being shipped by tank cars to various smaller purchasers in and outside of Kentucky. Because of the scattered nature of these customers, it has been impossible to secure figures which would be at all representative of their aggregate purchase. It is believed, however, that 30,000 barrels for 1918-1919 and 50,000 for the period of 1915 to 1919, inclusive, would be a very conservative estimate of the total amount of this scattered crude.

The American Pipe Line Company—Gainesville Pool to Bowling Green, 2-inch—has been such an uncertain factor in the transportation of the Gainesville crude that it has been impossible to obtain figures showing what runs have been made. This line is now in the hands of receivers and out of service. Altogether it probably never ran more than 20,000 barrels and wasted almost as much as this with old leaky pipe. Adding this figure to the one of the Indian Refining Company and the independent tank car purchasers a total production figure from 1915 to March 16, 1919, of 246,992.01 barrels is obtained.

The crude of Allen County coming from any one of the three pay "sands" below the base of the Devonian Black Shale is a mediumly dark green oil. It is opaqe—except in films less than one-eighth of an inch in thickness. Its base is paraffin. The gravity of this oil by the Baume scale will vary from 26.0 to 45.0, the latter of which is exceptional, and as taken from the records of the State Chemist, Dr. A. M. Peter, is the highest of any Kentucky crude oil. The average crude oil from this horizon in Allen County will run about 35 to 38 Baume. Unfortunately these Allen County limestone crudes exhibit, except

in some special instances, rather high sulphurs, 1.15% to 1.95%, which renders them difficult of refinement. All high sulphur oils are classed as "sour," and command in the open market a present day price somewhat less than $2.60, the generally uniform price for the bulk of Kentucky "Somerset" grade. The gasoline recovery of these crudes is, however, very good following a somewhat longer "treatment" than the oils of Eastern Kentucky. The following distillation record gives a fair idea of how the Allen County crudes run in commercial test.

Distillation Record of Scottsville, Allen County Crude.

Tank
Initial Boiling Point 300 — Gravity Baume 26.0
Temp. Condenser 80 — Maximum Boiling Point 650

Per Cent Off.	Temp. "F"	Gravity Be.	Per cent Off.	Temp. "F"
10	350	42.8	......	212
20	425	38.4	3.0	300
30	522	35.5	10.0	350
40	580	33.0	13.0	365
50	620	31.6	15.0	375
60	640	30.6	19.0	400
70	650	30.5	22.0	460
80	......	......	26.0	500
90	......	......	68.0	650
98	......	......	——	——
		Per Cent Total Recovery		......
		Loss in Gravity		......

32% Bottoms. 15.8 Grav.

Various ingenious methods have been devised by operators, geologists and promoters to estimate the amount of oil contained in the Allen County lower than Black Shale "sands." The writer's experience does not lead him to believe that any of these estimated—generally reckoned upon uncertain cubic space—are reliable. If any dependence could be placed in the regularity of porosity or quantity of oil per under-surface unit of 1000 square feet, some reliance might be placed upon the results thus obtained. But the chief characteristic of the producing sands of Allen County is their irregularity in porosity and productivity. It is believed that the old time-honored method of accurate well gauging over an extended period of time and considerable area

will prove to be the only safe guide as to the life of the wells of this section of Kentucky.

Naturally in so youthful an oil field as this, however, figures of this kind are as yet hardly obtainable, and where they are operators realizing the vital nature of such figures have hesitated to give them out. General deductions must, therefore, for the time being be used. The best information obtainable on Allen County shows that many correctly drilled and managed wells have started in with an initial flow from the pump of from 30 to 100 barrels. A few wells have flowed, and flowing wells when active and open to a tank, can easily do from 200 to 300 barrels every twenty-four hours. A very select group of wells in Allen County have probably done as much as 250 or 300 barrels per day for the first twenty-four hours after being "drilled in." Such exceptional wells have usually secured their pay from a very porous streak, generally 15 to 17 feet thick in the Onondaga (Corniferous) limestone. No one has ever published or boasted of a ten day test of any such well or group of wells, though their capacity is certainly known to their owners. This is significant, and it is thoroughly in keeping with the statement that these large capacity wells do not long maintain their high production record.

Allen County is essentially a shallow field—relatively easy and cheap to operate in. With these virtues it combines the feature common to all such fields of rapid and early decline of production. This decline is most notable in the larger wells. It may within practical limits of accuracy be figured at from 25 to 33 1-3 per cent by the end of the first month and with a gradually lessening decline during the second six months. This state of affairs need not cause undue concern either to the general public or the operators themselves for any group of fair size wells—30-150 barrels—will repay their initial cost and running expenes many times over before abandonment, providing they have the right kind of field supervision. Allen County wells as a rule are not well managed and this condition unless it is corrected will sooner or later militate against the production of the field.

In the small wells—5 to 20 barrels, and there are a great many of these in Allen County—the decline has shown itself to be

very much slower and of course very much lower in proportion to the total well production. While big production is what is alway desired, it is a fact, that with low developing costs such as are now existent in Allen and rapid commercial outlet for the crude—small wells can and are being drilled generally over this area with a substantial profit. Humorously enough it is the small well or group of small wells that determine whether an individual or corporation is an actual "oil producer" or not. Any one can ride along on "pot luck," big production, but it requires real oil producing management to head the small producing property. The reason is plain, for in the latter case the profit must come from the crude oil sales alone, and not from press agent stock inflation or Eldoradic speculation in the leases. Unfortunately Allen County—like the other producing sections of Kentucky—with its splendid bona fide record of recent new crude production has suffered much from this latter kind of unsound business.

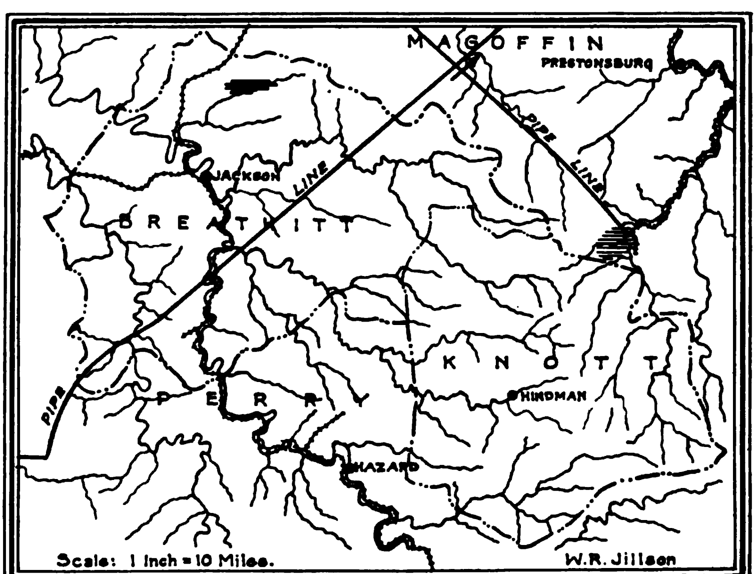
First Published July, 1919.

IX.

THE OIL AND GAS GEOLOGY OF BREATHITT AND KNOTT COUNTIES.

Introduction.

The area upon which this report is based occupies a central position in the hill region or what is commonly called the "Mountains" of Eastern Kentucky. This section lies between 37° 10′ and 37° and 45′ north latitude and 82° and 45′ and 83° and 45′ west longitude. Geographically this area is the

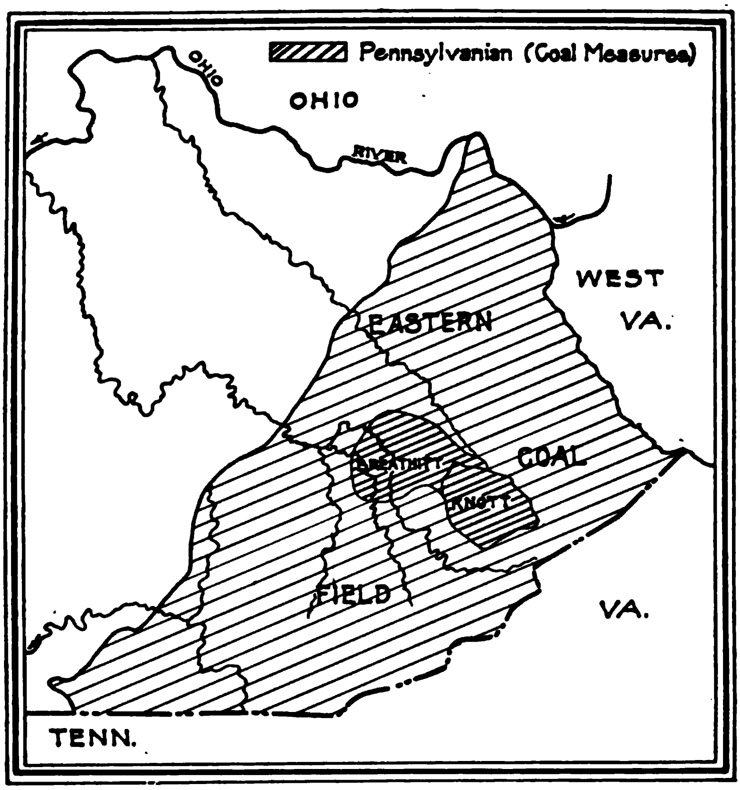


Sketch map of Breathitt and Knott Counties, Ky., showing drainage and railroads.

central interior of the Eastern Kentucky Coal Field. The principal towns within the section are Jackson, county seat of Breathitt County, on the North Fork of the Kentucky River, and Hindman, county seat of Knott County, on the headwaters of Troublesome Creek, a northwest flowing tributary of the North Fork of the Kentucky River.

FIELD WORK.

The field work upon which this report is based, including the accompanying structural maps, was done by the writer and Mr. Iley B. Browning, Assistant Geologist. The writer made six geological reconnaissances of both Breathitt and Knott counties during the years 1917, 1918 and 1919. The structural mapping was done by Mr. Browning, during the spring and summer



Sketch map showing location of Breathitt and Knott Counties in the Eastern Kentucky Coal Field.

of 1919. The levels were run from bench marks of known elevation above sea level. Radiating elevations were placed from these points on the Fire Clay Coal, which was used as the key bed.

Annotated Bibliography.

The published literature relative to the oil and gas of Breathitt and Knott counties is very scant indeed. Much has been written on the coals of this section and their sequences and thickness are now very well understood. The stratigraphy and structural geology of this section, however, have received practically no attention at all. The following bibliography of maps and reports it is believed completely covers all publications touching directly on the oil and gas geology of these two counties.

Topographic Maps.

(30′ Minute Base.)

Manchester—1891

Scale 1-125000. Contour interval 100 feet. Reprinted 1917. U. S. G. S. Reconnaissance topography.

Beattyville—1892

Scale 1-125000. Contour interval 100 feet. Reprinted 1916. U. S. G. S. Reconnaissance topography.

Salyersville—1899

Scale 1-125000. Contour interval 100 feet. Reprinted 1918. U. S. G. S. Reconnaissance topography.

Buckhorn—1913 (15′ Minute Base.)

Scale 1-62500. Contour interval 50 feet. U. S. G. S. and Kentucky Geol. Survey. Excellent map, accurate in detail.

Troublesome—1914

Scale 1-62500. Cotour interval 50 feet. U. S. G. S. and Kentucky Geol Survey. Excellent map, accurate in detail.

Whitesburg—1915

Scale 1-62500. Contour interval 50 feet. U. S. G. S. and Kentucky Geol. Survey. Excellent map, accurate in detail.

HINDMAN—1915

Scale 1-62500. Contour interval 50 feet. U. S. G. S. and Kentucky Geol. Survey. Excellent map, accurate in detail.

PIKEVILLE—1916

Scale 1-62500. Contour interval 50 feet. U. S. G. S. and Kentucky Geol. Survey. Excellet map, accurate in detail.

PRESTONSBURG—1918

Scale 1-62500. Contour interval 50 feet. U. S. G. S. and Kentucky Geol. Survey. Excellent map, accurate in detail.

GEOLOGICAL MAPS.

PROCTER, JOHN R.—1891

Preliminary map of Kentucky, Kentucky Geological Survey. Scale 20 miles equal one inch. Very general and inaccurate. Designates coal measures as the exposed strata of Breathitt and Knott counties. (Out of print.)

PROCTER, JOHN R.—

Map of Kentucky. Eclectic Geographies. Scale 26½ miles equal one inch. A reconnaissance geological map of Kentucky; very generalized and inaccurate. Shows the surface rocks of Breathitt and Knott counties to be those of the coal measures entirely. (Out of print.)

HOEING, J. B.—1907

Preliminary map of Kentucky. Kentucky Geological Survey, Series IV, scale one inch equals 10 miles. Shows aerial geology of Breathitt and Knott counties to be Pennsylvanian.

SELLIER, L. M.—1915

Preliminary map of Kentucky. Kentucky Geological Survey, Series IV, cale one inch equals 10 miles. Shows aerial geology of Breathitt and Knott counties to be Pennsylvanian.

· 1917

SELLER, L. M.—

(Same as above.)

GEOLOGICAL REPORTS

OWEN, DAVID DALE—1857

Coal measures. Kentucky Geological Survey, Series I, third report of the Geological Survey in Kentucky. Chapter I, pages 9-30, Discusses coal measures correlations and on page 30 states that "a similar coal series exists in Breathitt County" as that in the neighboring counties of Morgan, Wolfe and Owsley. First definite stratigraphic reference. (Out of print.)

MOORE, P. N.—1878

Report on the geology of a section from near Campton, in Wolfe County, to the mouth of Troublesome Creek, in Breathitt County. Kentucky Geological Survey, Series I. (N. S. Shaler, Director), pages 255-284, and also reprint Kentucky Geological Survey, Series II (John R. Proctor, State Geologist), pages 254-289, 1884. Discusses the coal measure stratigraph structure of northwestern Breathitt County along general lines. (Out of print.)

HODGE, JAMES M.—1885

Preliminary report on the geology of parts of Letcher, Harlan, Leslie, Perry and Breathitt counties. Kentucky Geological Survey, Series II, Vol. C., Part 2, pages 35-52a. Also An. Report, Kentucky Inspector of Mines, 1901-1902. General structural relations outlined Description of coal openings and sequences. (Out of print.)

Preliminary report on the geology of the Lower North Fork, Middle and South Forks, Kentucky River. Kentucky Geological Survey, Series II, Vol. C., Part 2, pp. 57-114; also An. Report, Kentucky Inspector of Mines, 1901-1902. Stratigraphic and structural references to Breathitt County. Principally a description of coal openings and sequences. (Out of print.)

Hoeing, J. B.—1905

Oil and Gas Sands of Kentucky. Kentucky Geological Survey, Series III, Bull. I, 233 pages and three maps. Many references to oil and gas sands of Breathitt and Knott counties, including well logs. (Out of print.)

Hodge, James M.—1910

Report on the Coals of the Three Forks of the Kentucky River. Kentucky Geological Survey, Series III. Bull. II and one large map. Analyses and descriptions of the coals of this section of Kentucky. (Out of print.)

Miller, Arthur M.—1910

Coals of the Western Border of the Eastern Coal Field. Kentucky Geol. Surv., Series III, Bull. 12, 83 pp., 7 pls. (maps and sections). Dicusses Pottsville in general and Breathitt and Lee formations. Maps a small section in the northwestern part of Breathitt county. (Out of print.)

Fohs, F. Julius—1912

Coals of the Region Drained by the Quicksand Creeks. Kentucky Geological Survey, Series III, Bull. 18, Serial 25. Contains stratigraphic sequence of the coals; detailed section and analyses. Eight sketch maps. This report is essentially an operator's and prospector's guide to the coals of this section of Breathitt County.

HODGE, JAMES M.—1913

Coals of the North Fork of Kentucky River, in Perry and Knott counties. Kentucky Geological Survey, Series IV, Vol. I. Part II, pages 923-986. Operator's description of coals and analyses.

Coals of Upper Carr Fork and the Big Branch and Bull Creek Region of North Fork of Kentucky River. Kentucky Geological Survey, Series IV, Vol. I, Part II, pages 987-1036. Operator's description of coals and analyses.

HODGE, JAMES M.—1918

Coals of the North Fork of the Kentucky River, in Perry and portions of Breathitt and Knott counties. Kentucky Geological Survey, Series IV, Vol. III, Part III, 418 pages. Descriptions of the coals, their sequence, etc. Operator's guide.

JILLSON, W. R.—1919

Structural Deformation and its Relation to Proven Oil and Gas Accumulation in Eastern Kentucky. Department of Geology and Forestry of Kentucky, Series V, Mineral and Forest Resources, Vol. I, No. 2, Paper No. 1. One map. References to Breathitt and Knott County Structure. (Out of print.)

The Low Sulphur Coals of Kentucky. Department of Geology and Forestry of Kentucky, Series V, Mineral and Forest Resources, Vol. I, No. 2, Paper No. 8. Gives stratigraphic sequence for Breathitt and Knott counties. (Out of print.) 1919.

The Oil and Gas Resources of Kentucky. Department of Geology and Forestry of Kentucky, Series V, Bull. I. Discusses Oil and Gas Geology, structure, stratigraphy, well logs and development of Breathitt and Knott counties. 1919.

PHYSIOGRAPHY

The area under discussion forms a unit with the remainder of the "Mountain" section and is essentially a maturely dissected northwetward sloping plateau. The valleys are "V" shaped and narrow; the ridges knifelike and irregular. There is no single extensive area of flat or plain land in either county, the largest flats occurring only in the big meandors of the North and Middle Forks of the Kentucky River.

The lowest elevation in Breathitt County is found at the point where the North Fork of the Kentucky River enters Wolfe County. This elevation is about 650 feet. The highest point in Breathitt County is 1685 feet, which is found at the head of Jake's Fork of the Laurel Branch of Troublesome Creek, in the southeastern section of the county, on the Perry County line. The elevation of Jackson is lower than a medial position between these two extremes, the elevation of the L. & E. railroad station at Jackson being 762 feet. The relief in Breathitt County varies between 450 feet and 700 feet, the highest relief being found on the headwaters of the creeks, on the ridges bordering Breathitt and Perry, on the south, and Breathitt and Magoffin on the north.

The lowest point in Knott County is found at the mouth of Jones' Creek, where it empties into Right Beaver Creek, and is 700 feet above sea level. Occurring on Right Beaver Creek, a tributary stream to the Levisa Fork, this low point belongs in the drainage basin of the Big Sandy River. The lowest point in Knott County in the Kentucky River drainage is found on the boundary of Breathitt and Knott counties, on Buckhorn Creek, at the mouth of Cole's Fork. This elevation is 866 feet, giving the minimum Kentucky River drainage an increased elevation over the minimum Big Sandy River drainage of 166 feet. The highest points in Knott County are between 2,250 and 2,300 feet. These are found in the ridge divide between Knott and Letcher counties, in the vicinity of Omaha post office, on the head of Carr's Fork of the North Fork of the Kentucky River. The maximum elevations of Yellow and Chestnut Mountains, which are found in the north central portion of Knott County, between the Kentucky River and the Big Sandy River drainage basins,

are from 1,750 to 1,800 feet above sea level. There are in Knott County, however, especially in the southeastern section, many elevations of 1,800 and 1,900 feet. The elevation of Hindman (U. S. G. S., B. M.) is 1,032 feet. The differences in relief in the Big Sandy River drainage basin amount to about 1,500 feet between the highest and lowest points. The differences of relief in the Kentucky River drainage basin amount to 1,200 feet between the highest and lowest points. An average relief of from 600 to 800 feet is common throughout Knott County between ridge elevation and elevations in the creeks immediately below.

DRAINAGE

The principal drainage lines are the North and Middle Forks of the Kentucky River, which flow northwestward, respectively, across the central and western portions of Breathitt County. Smaller tributary streams are Frozen Creek, Quicksand Creek and Troublesome Creek, of the North Fork of the Kentucky River, in Breathitt County, and Carr's Fork, Ball's Fork, Laurel Fork, Middle Fork, Jones' Fork, Caney Creek and Dry Creek, of Knott County. The Knott County drainage is all headwater drainage, the streams of the western portion of this county flowing into the North Fork of the Kentucky River, and the streams of the eastern portion of the county flowing into Right Beaver Creek, of the Levisa Fork of the Big Sandy River. The streams individually afford excellent examples of entrenched meandors. Collectively they illustrate splendidly the entrenchment of entire drainage sytems. Rapids or waterfalls are very rare, and swamped or ponded aieas are unknown. Due to the clastic silicious nature of the sediments of this section, mechanical factors are the important erosive agents, solution playing a very minor part. The area is covered with a thick stand of original and secondary growth timber, chiefly of the broad leaf varieties of oak, maple, poplar, etc. The heavy stand of timber, coupled with thick undergrowth of bushes and smaller vegetation, has resulted in obscuring the stratigraphy of the section to a very marked degree, making geological work very difficult.

TRANSPORTATION

The roads, with the exception of those points where they cross the ridges, are always found down in or alongside of the creeks. No automobile roads and very few good wagon roads are found in either county. Horseback riding is the common method of travel. The Louisville & Nashville Railroad following the North Fork of the Kentucky River bisects Breathitt County, but no passenger railroad crosses or enters Knott County. The Beaver Creek division of the Chesapeake & Ohio Railroad serves Hindman, however, through Lackey Station in Floyd County.

STRATIGRAPHY

The exposed or surface rocks of Breathitt and Knott counties are, with the exception of small amounts of unconsolidated alluvial deposits along the larger streams, all of marine or semi-marine sedimentary origin. Omitting the coals and one or two rather thin calcareous horizons these sedimentary rocks are all clastics, that is, they are composed of a material of a fragmental nature, derived by mechanical erosional means from other older land surfaces, and have all been deposited in or by water.

Excepting the river aluvium, which is a recent deposit, all of the exposed rocks in this section belong to the Alleghany and the Pottsville divisions of the Pennsylvania system. The principal exposures are those of the Wise-Kanawha or Upper Pottsville, which section attains a maximum thickness of between 1,200 and 1,500 feet in this region. The representatives of the Alleghany are found only in a few of the higher ridges, where they exist as isolated remnants of a one time continuous and blanketing formation. In both the Alleghany and the Pottsville there are found many coal seams, but due to their restricted aerial distribution and high position, the coals of the Alleghany are economically unimportant and few. The sequence of the important commercial coals of the Pottsville, as now known in advance of any considerable amount of coring beneath the drainage levels, is given herewith. The area of elevation is that adjoining Lambric post office, on Quicksand. Creek, Breathitt County. It may be pointed out that these elevations are variable at all points, heightening with the thickening interval to the southeast, and lessening with the corresponding thinning of the intervals to the northwest.

COALS OF THE WISE-KANAWHA-UPPER POTTSVILLE

	Alt. Feet.
Hindman coal	1400
Interval 80 to 100.	
Flag coal (No. 7)	1335
Interval 40 to 80.	
Hazard coal (No. 6)	1275
Interval 100 to 150.	
Haddix coal (No. 5)	1093
Interval 200 to 235.	
Fire Clay coal (No. 4)	850
Interval 30 to 50.	
Whitesburg coal	800
Interval 120.	
Amburgy coal.	
Interval (unknown).	

From the Amburgy coal down to and below drainage there is an undetermined thickness of the Upper Pottsville, the coals of which in Breathitt and Knott counties are imperfectly known. Beneath these lie the representatives of the Norton-New River or Middle Pottsville, and the representatives of the Lee-Pocahontas or Lower Pottsville, which sub-surface formation completes the Pennsylvanian system in this section.

Beneath the Lowest Pottsville are found representatives of the Mississippian System, Devonian System, Silurian System and Ordivician System. A complete generalized section for this region, including the exposed surface rocks as well as the underlying, below drainage strata, has been prepared and is here presented.

STRATIGRAPHIC SEQUENCE ABOVE AND BELOW DRAINAGE IN BREATHITT AND KNOTT COUNTIES

PENNSYLVANIAN SYSTEM	Minimum Thickness Feet	Maximum Thickness Feet
Alleghany Upper Pottsville	1000	1500
Drainage Average Level.		
Upper Pottsville Middle Pottsville Lower Pottsville	500	1650

MISSISSIPPIAN SYSTEM			
Mauch Chunk; Ste. Genevieve-St. Louis; Waverly	....	800	1000
DEVONIAN SYSTEM			
Black Shale; Onondaga Limestone	....	300	400
SILURIAN SYSTEM			
Niagara; Clinton	....	175	300
ORDOVICIAN SYSTEM			
Trenton; Lower Strata	....	(unknown)	

As stated above, the rocks of the Alleghany and the Pottsville of the Pennsylvanian System, with the exceptions already noted, are clastics—gritty shales, true silicious sandstones and sandy conglomerates. The rocks of the Mississippian System may be subdivided into the (1) Mauch Chunk, (2) St. Genevieve-St. Louis, and the (3) Waverly. The Mauch Chunk is composed of alternating sandstones and pinkish or reddish to purple shales, which grade downward into bastard limetones. The St. Genevieve-St. Louis group is composed of two distinct and easily recognized thick and compact limestones, with a thin sandstone parting. The Waverly consists in downward succession of alternating shales and sandsones, most of which in the upper section have a pinkish or red color. Toward the base of the Waverly the sections show a thick succession of sandy and limy shale of light gray to blue color, which is terminated by a thin dark shale, the Sunbury, and a thin sandstone of tan or gray color. This sandstone may or may not be a fingering out of the well known Berea. The Devonian System is composed of two members, the Black Shale, correlative to the Ohio, Chattanooga, and Genesee shales. Beneath that is found a true magnesian limestone, somewhat cherty, which is the correlative of the Onondaga limestone and is commonly known as the Corniferous from its cherty or hornstone lithological characteristic. This limestone may be porus or compact. It is the Irvine sand of drillers and is the horizon which is chiefly productive to the north and northwest of Breathitt County, in the Estill-Lee-Wolfe-Powell section. Beneath the Devonian, the Silurian System presents an

increasingly limy tendency, with alternating hard, sandy and shaly limestones, which exhibit variegated colors from gray to green to pink. The pronounced reddish limestone horizon found toward the base of this system is the Clinton, well known among drillers, and is easily recognized by its reddish color. The Ordivician System underlying the Silurian presents a monotonous succession of compact limestones, shaly limes, and irregularly distributed thin sand lenses. Nothing lower than Ordivician has ever been touched by the drill in either Breathitt or Knott County, as the Ordivician System in this section is extremely thick.

The Pottsville and Mauch Chunk

The stratigraphy of Breathitt and Knott counties, simple in its general conceptions, presents many specific irregularities and complications. The outstanding important feature found in all formations above the Devonian is that of extreme irregularity, and a general progressive thickening especially in the Pottsville from the northwest toward the southeast. This thickening in the Pottsville, a perfectly definite and easily demonstrated fact, may be counted upon with certainty to change the sub-surface structure to some extent over that which is seen and mapped at the surface on any of the coals or other less dependable and definite indexes or key bed horizons. Below the Pottsville the thickening in the underlying formations down to the Devonian is not nearly as noticeable or as important.

The irregularity of the surficial as well as the subsurface stratigraphy of these two counties may be said to be both interformational and inter-systemal. The Pottsville, of the Pennsylvanian, and the Mauch Chunk, of the Mississippian, illustrate perhaps to the best advantage the great irregularity in sequence of sands and shales, hardly any two well records exhibiting the same intervals or corresponding lithology. With the exception of the Beaver sand in the Pottsville, which is generally easily recognized, due to its thickness and persistency, the sands and shales present an extremely variable succession. There are, however, in the Pottsville three important oil and gas sands.

These are the Beaver, Horton and Pike. Occasionally at the base of this section there is found a rather thick sand in addition to the above named three, which may be called the Stray or Salt sand.

Between the Mauch Chunk and the Pottsville there exists in this part of Kentucky a very great unconformity, with the result that the Mauch Chunk, which has been channelled and cut up by the currents of the earliest Pottsville embayment, presents an extremely variable thickness. The Pottsville in many places has been dropped down into channelled incisions in the Mauch Chunk. At such places records show additional sands in the Pottsville and a very thin representation of the Mauch Chunk. In other and closely adjoining locations a greater or complete section of the Mauch Chunk is frequently found. In such places the Mauch Chunk generally gives one or two definite, true silicious sands, which are oil and gas bearing. These sands are intercalated between thick pinkish to reddish shales. The chief productive horizon in the Mauch Chunk is the Maxon sand, a name brought to Kentucky from West Virginia, where the sand was first found productive and became established. This sand has not shown any large production to date in Breathitt County, but is very productive in Knott and the adjoining county of Floyd. It is also productive in a limited way to the southwest of Breathitt County, in Knox County.

The St. Genevieve-St. Louis-Waverly Group of the Mississipian System is perhaps the most regular and most easily recognized horizon in all of the subsurface stratigraphy, with the exception of the Devonian Black Shale. The St. Genevieve-St. Louis Group sand inclusion is productive of gas in Knott County toward the head of Rock Fork on the Bolin farm, and this horizon may be looked to for further gas production in other sections of Breathitt ad Knott counties. The upper part of the Waverly, commonly known as the Big Injun, offers one or two sands, which are productive of gas. The possibility of oil production from this horizon is, however, somewhat remote, though it is a fact that these rocks do produce a small quantity of oil in some parts of eastern Kentucky. No sands of importance from a commercial standpoint are recognized in the lower Waverly. The Wier and Berea sands, when followed along the outcrop to the northwest, are seen rapidly to thin to the south and prob-

ably do not extend far enough south to cover this entire area, at least as an important oil and gas sand. The Wier, however, at almost every point where it has been drilled haa given shows of oil, even as far south as the well at Wolf Coal in Breathitt County.

The Black Shale, Onondaga Limestone, and Lower Strata

The Devonian Shale has not been drilled into production at any point within these two counties, though it occasionally exhibits a sandy lense-like phase. The Onondaga, or "Corniferous" Limestone, underlying the Black Shale has been penetrated by the bit in many places, but has to date proven unproductive in this whole area, except in a few wells in the northwesternmost part of Breathitt County, where small production has been obtained. Lower than the Onondaga no oil or gas sands of importance are recognized to date in the Niagara or the Trenton in either of these counties, and were any such sands ever to be found productive, they would only be reached at considerable depth.

BREATHITT COUNTY.

LOG No. 1.

OLD WELL ON FROZEN CREEK.

Strata	Thickness	Depth
PENNSYLVANIAN SYSTEM.		
Clay	12	12
White sand	53	65
Bastard lime (?) Oil show	2	67
White sand	73	140

A BREATHITT COUNTY GASSER.

This well is located on the Wilhurst Anticline and produces about 3,000,000 cubic feet of natural gas, with a rock pressure of 500 pounds. Notice the frost on the tubing. This well was drilled by the Big Six Oil Co. Photo by W. R. Jillson, 1919.

LOG No. 2.

J. H. WINTERBOTHAM FARM

Little Frozen Creek.

Strata	Thickness	Depth
PENNSYLVANIAN SYSTEM.		
Soil	11	11
Sand	90	101
Slate	50	151
Sand	274	425
Slate	30	455
Sand	30	485
MISSISSIPPIAN SYSTEM.		
Lime "Big Lime"	175	660
Sand	50	710
Shale (Waverly)	400	1110
Brown shale (Sunbury)	10	1120
Sand (Berea?)	35	1155
DEVONIAN SYSTEM.		
Brown shale	218	1373
Sand (?)	3	1376
Lime	11	1387
Brown lime—oil	11	1398
Sand (?)	6	1404

LOG No. 3.

BRECK CRAWFORD FARM.

Mouth of Cope's Branch.

Strata	Thickness	Depth
PENNSYLVANIAN SYSTEM.		
Soil	8	8
Lime	22	30
Sand	55	85
Slate	15	100
Sand	62	162
Slate	5	167
Sand	13	180
Slate	90	270
Sand	80	350
Slate	7	357
White sand	80	437
Brown slate	3	440

MISSISSIPPIAN SYSTEM.		
Sandy lime	3	443
Sandy slate	29	472
Sandy lime	18	490
Slate	16	506
Lime—"Big Lime"—Gas at 620	204	710
Sandy shale	10	720
White shale	32	752
Sand	143	895
Sandy shale	290	1185
DEVONIAN SYSTEM.		
Brown shale	159	1344
Black shale	3	1347
Lime shell	1	1348
Sandy shell	14	1362
Black shell	18	1380
Brown lime	20	1400
White lime	35	1435
Sandy lime—oil and water at 1460	112	1547
Blue sandy shale	10	1557
Brown lime	10	1567

LOG No. 4. HARGIS FARM.

Four miles up South Fork of Quicksand Creek.

Strata	Thickness	Depth
PENNSYLVANIAN SYSTEM.		
Sand and gravel	12	12
Sand	53	65
Coal	2	67
Slate	23	90
Coal	2	92
Sand	10	102
Slate	43	145
Coal	3	148
Sand	10	158
Slate	9	167
Coal	3	170
Slate	70	240
Sand	10	250
Slate	37	287
Sand	60	347
Slate	10	357
Sand	200	557
Slate	93	650
Sand	200	850
Slate	5	855
Sand (Base of Pottsville)	115	970

MISSISSIPPIAN SYSTEM.		
"Little lime"	25	995
"Pencil cave"	5	1000
"Big lime"	190	1190
Blue sand	100	1290
Red rock	40	1330
Sandy slate	175	1505
*"Berea Grit" (?) —Oil and gas show	70	1575
Slate	30	1605
DEVONIAN SYSTEM.		
Black shale (Devonian)	275	1880
White slate	30	1910
Lime	114	2024
Slate	2	2026

LOG No. 5. **DAVIS FARM.**

7 miles up South Fork of Quicksand Creek.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Sand	15	15
Slate	25	40
Lime	10	50
Slate	425	475
Sand	100	575
Slate	10	589
Sand	30	615
Slate	5	620
Sand	280	900
Slate (Base of Pottsville)	90	990
MISSISSIPPIAN SYSTEM.		
"Little lime"	25	1015
White sand	55	1070
Lime	10	1080
Slate	15	1095
Lime	21	1116
"Pencil cave"	2	1118
"Big lime"	182	1300
Blue sand	80	1380
Red rock	77	1457
Slate	108	1565
Sand	10	1575
Slate	37	1612
Wier	40	1652
Break	9	1657
"Berea" (?)	68	1725

*The Berea probably does not extend as far south as the well.

DEVONIAN SYSTEM.

Black slate	305	2030
White slate	25	2055
SILURIAN SYSTEM.		
Lime	175	2230
Sand	60	2290
Slate	40	2330
Red rock	70	2400
Blue slate	50	2450
Red rock	50	2500

LOG No. 6.

WELL ON WOLF CREEK AT WOLF COAL.
Big Bird Oil & Gas Co.
T. H. Drake, Contractor and Driller.
(Partial record.)

Strata	Thickness		Total Depth
PENNSYLVANIAN SYSTEM			
Top soil	10		10
Broken lime	5		15
Blue slate	115		130
Sand	15		145
Slate	5		150
Sand	25		175
Shale	2	Cased with 177-8¼	177
Black slate	123		300
Sand	150	Called salt sand	450
Shale	100		550
Sand	126		676
Coal	10		686
Shale	150		836
Sand	84		920
MISSISSIPPIAN SYSTEM.			
Shale	80		1,000
Sand	70	Showing of oil	1,070
Red rock	30		1,100
Lime shell	5	Cased with 6¼ casing	1,105
Sand	50		1,155
Shale	50		1,205
Broken lime	45		1,250
Big lime	115	Oil and Gas flowed 60 hours	1,365
Big lime	50		1,415
Lime shell	10	Green in color	1,425
Shale	90	Red rock	1,515

*Berea probably not this far south.

Blue slate	150		1,665
Sand	50	Wier	1,715
Shale	35	Green	1,750
Shale	30	Light	1,780
Sand	20	Berea	1,800
Shale	15	Pink	1,815
Shale	15	Light	1,830
DEVONIAN SYSTEM.			
Brown shale	210		2,040
Shale	10	Light	2,050
Brown shale	25		2,075
Sand shale	25		2,100
Corniferous lime	100	In and still drilling.	

LOG No. 7. ELKATAWA.

Well on Caney Creek near Elkatawa.

R. A. Chiles, et al.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Soil	1	20
Pottsville	565	585
MISSISSIPPIAN SYSTEM.		
Shale	55	640
Little lime	13	653
Shale	2	655
Big lime	145	800
Big Injun	90	890
Red rock slate	385	1275
Berea	25	1300
DEVONIAN SYSTEM.		
Brown shale	260	1560
White slate	7	1567
Cap rock	25	1592
Sand (small oil flow)	1	1593
Sand (small salt water flow)	3	1596
Hard dry sand	......	....

(This record incomplete.)

LOG No. 8.

BIG BRANCH OF NORTH FORK NEAR HADDIX.

PENNSYLVANIAN SYSTEM.

Strata	Thickness.	Depth.
Surface	8	8
Sand rock	12	20
Shale	2	22
Coal	3	25

Blue mud	5	30	
Sand rock	15	45	
Water sand	5	50	top water
Sand rock	7	57	
Black shale	13	70	
Blue mud	40	110	
Blue grit	55	165	hard.
Black shale	60	225	
Sand rock	25	250	
Blue shale	10	260	
Fire clay	8	268	
Sand rock	12	280	
Blue mud	45	325	
Sand rock	15	340	
Black mud	50	390	
Sand rock	181	571	hard.
Black slate	37	608	
Sand rock	50	658	
Black slate	87	745	3′ coal.
Sand rock	185	930	
MISSISSIPPIAN SYSTEM.			
Red rock	5	935	
White slate	5	940	
White grit	170	1110	100′ in water
Slate	30	1140	
Lime	20	1160	
Slate	8	1168	
Big lime	222	1390	
Black lime	20	1410	
Lime shells	10	1420	
Shale	5	1425	
Red Rock	40	1465	Big Injun.
Brown shale	30	1495	
Blue slate	55	1550	
Lime shell	25	1575	
Slate	184	1759	
DEVONIAN SYSTEM.			
Brown shale	253	2012	
Blue mud	2	2014	
Brown shale	42	2056	
Fire clay	12	2068	
Sand (Corniferous Limestone)	212	2180	

(Base of Devonian and top of Silurian occur in the last 235 feet and the change was not noted by the driller.)

KNOTT COUNTY

LOG. No. 9.

WELL AT THE MOUTH OF MILL BRANCH OF BALLS FORK.
5½ miles north of Hindman.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Soil	10	10
Light shale	10	20
Sand	4	24
Coal	5	29
Dark slate	5	34
Gray sand	32	66
Coal	3	69
Light slate	15	84
Sand	16	100
Slate	20	120
Gray sand	27	147
Coal	3	150
Black slate	16	166
White sand	44	210
Coal	4	214
Black slate	34	248
Gray sand	15	263
Light slate	60	323
White sand	12	335
Light slate	30	365
Coal	4	369
Dark slate	70	439
Gray sand	12	451
Light slate	54	505
Sand	20	525
Black slate	128	653
White sand	37	690
Dark slate	62	752
White sand	25	777
Shelly slate	188	965
White sand (Beaver)—Gas and salt water	215	1180
Black slate	20	1200
Sand (Horton)	126	1326
Dark slate—Salt water	12	1338
White sand (pike and salt)—Salt water	312	1650
(All in Pottsville.)		

LOG No. 10. J. M. CONLEY FARM.

Head of Salt Lick of Right Beaver.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Drift	22	22
Slate	30	52
Sand	20	72
Coal	2	74
Dark slate	45	119
Gray sand	3	122
Dark slate	23	145
White sand	49	194
Slate	54	248
White sand	47	295
Dark slate	50	345
White sand	48	393
Dark slate	45	438
White sand	30	468
Dark slate	70	538
Gray and white sand (Beaver and Horton)	300	838
Coal	2	840
Dark slate	39	879
Gray and white sand (Pike)—Salt water	105	984
Dark slate	25	1009
Gray sand	15	1024
Slate	156	1180
White sand (salt sand) Oil and salt water	28	1208
(All Pottsville.)		

LOG No. 11. WEBB FARM.

Right Beaver above Jones Fork.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Soil	35	35
Coal	5	40
Sand	40	80
Black slate	80	160
Light slate	70	230
Coal	3	233
Slate and sand	207	440
White sand (Beaver)	40	480
Slate	20	500
White sand (Horton)—Gas, oil and salt water	220	720
Slate	5	725

Sand (Pike) Salt water	127	852
Slate	35	887
Black sand	25	912
White sand (salt sand)	94	1006
Black slate (base of Pottsville).		
(All Pottsville.)		

LOG No. 12. WM. TRIPLETT FARM.

Jones Fork of Right Beaver.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Sand and gravel	31	31
Slate	9	40
Coal	3	43
Slate and shells	80	123
Black shale	27	150
Sand	50	200
Slate	30	230
Sand	20	250
Black slate and shells	150	400
Sand—Gas	10	410
Slate	25	435
Sand (Beaver)	180	615
Slate	30	650
Sand (Horton)	130	780
Slate and sand	100	880
Sand (Pike)—Black oil at 990	110	990
Black slate	10	1000
Slate and shells	51	1051
Sand (salt sand)	45	1096
(All Pottsville.)		

LOG. No. 13. LINDSAY TRIPLETT FARM.

Jones Fork of Right Beaver.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Soil	36	36
Slate	6	42
Black sand	160	202
Gray sand	110	312
Slate and shells	160	472
Gray sand (Beaver)	100	572
Slate	5	577
White sand (Horton)—Salt water	203	780
Slate and shell	75	855
Black sand	20	875

Slate	25	900
White sand (Pike)	125	1025
Slate	25	1050
White sand	75	1125
Slate	20	1145
White sand (Salt sand)	30	1175
Black slate	5	1180
White sand —Salt water	32	1212

(All Pottsville.)

LOG No. 14. WM. INMAN FARM.

Rock Fork of Right Beaver.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Soil	24	24
Slate	30	54
Sand	12	66
Slate	19	85
Coal	2	87
Slate	45	132
Sand	15	147
Slate	41	188
Sand—Salt water	45	233
Slate	68	301
Sand	8	309
Slate	127	436
Sand	20	456
Slate	6	462
Sand	18	480
Slate	8	488
White sand (Beaver)	79	567
Slate (Beaver)	3	570
White sand (Beaver) —Gas and salt water	115	685
Slate	2	687
Sand	22	709
Slate	38	747
White and gray sands (Horton)—Salt water	124	871
Black slate	2	873
Gray sand—Oil show	20	893
Black slate	2	895
White sand (Pike)—Salt water	121	1016
Black slate	35	1051
White sand (salt sand)—Oil and salt water	106	1157

(All Pottsville.)

LOG No. 15. ESTHER HORTON FARM.
Rock Fork of Right Beaver.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Soil	21	21
Slate	100	121
Sand	14	135
Slate	41	176
Sand	36	212
Slate	3	215
Sand	35	250
Slate	151	401
Sand	9	410
Slate	35	445
White sand (Beaver)	213	658
Coal	2	660
Sand	30	690
Coal	2	692
Slate	31	723
Sand (Horton)—Oil	89	812
Slate	12	824
Black sand	11	835
Black slate	9	844
Sand	13	857
Slate	5	862
White sand (Pike)—Gas, oil and salt water	136	998
Black slate	17	1015
Sand (salt sand)—Gas	124	1139
(All Pottsville.)		

LOG N. 16. ANDY COBURN FARM.
Rock Fork of Right Beaver.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Drift	26	26
Slate	38	64
Sand	16	80
Coal	6	86
Slate	9	95
Sand	20	115
Slate and red shale	145	260
Coal	8	268
Slate	67	335
Sand	50	385
Slate	77	462

Sand	10	472
Slate	74	546
Sand (Beaver)—Oil and gas	148	694
Slate	14	708
Sand (Horton)—Salt water	115	823
Slate	14	837
Gray sand } (Pike) —Salt water	120	927
Slate } (Pike)	28	955
White sand } (Pike)	126	1111
Slate	35	1146
Sand and slate	27	1173
Gray and white sands } (Salt sand) —Salt water	31	1204
Black slate } (Salt sand)	18	1222
White sand } (Salt sand) —Salt water	41	1263
(All Pottsville.)		

LOG No. 17. ANDY COBURN FARM.

Rock Fork of Right Beaver.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Soil	20	20
Slate	39	59
Sand	21	80
Slate	12	92
Coal	8	100
Sand	42	142
Slate	48	190
Sand	48	238
Slate	242	480
Sand (Beaver)—Gas and salt water	28	708
Slate	44	752
Sand	20	772
Slate—Salt water	16	788
Sand—(Horton)	63	851
Black slate	12	863
Gray sand	9	872
Black slate	9	881
White sand } (Pike)	52	933
Black slate } (Pike)	4	937
White sand } (Pike)	82	1019
Black slate	28	1047
White sand } (Salt sand	51	1098
Slate and shells } (Salt sand	21	1119
White sand } (Salt sand —Salt water	29	1148
(All Pottsville.)		

LOG No. 18. ROCK FORK JUST BELOW BRUSHY FORK.

Lessor, W. R. Bolen No. 1. Total depth 1,635 feet.

Strata	Thickness.	Depth.
Drift 20 feet 10" casing		20
PENNSYLVANIAN SYSTEM.		
White sand	5	25
Coal	5	30
Dark slate	120	150
Dark sand 8" casing	30	180
Slate	5	185
Sand	30	215
Coal	5	220
Slate	20	240
Sand	70	310
Slate	15	325
Sand	95	420
Slate	15	435
Sand	45	480
Slate	280	760
Sand	148	908
Break	2	910
Sand (water at 950)	80	990
Break	10	1000
Sand (little oil at 1060 feet)	170	1170
Slate	10	1180
Sand	40	1220
MISSISSIPPIAN SYSTEM.		
Limestone	20	1230
Sand	40	1270
Slate	30	1300
"Maxon" sand (a little water and oil at 1305)	123	1423
Black slate	14	1437
Sandstone, light sandy	13	1451
Slate and shells	25	1476
Little lime	15	1491
Pencil cave	9	1500
"Big lime"		
Gas in Big Lime at 1630	135	1635

4,680,000 cu. ft. gas, open flow 540 pounds rock pressure.

Well completed July, 1916. 1637 2" tubing.

Not shot. Elevation 945 feet.

1440 6⅝" casing.

A. B. Brode and Son, Contractors. S. L. Anderson, Driller.

135 feet not the full thickness of the Big Lime formation which in this locality should be about 160 to 180 feet thick.

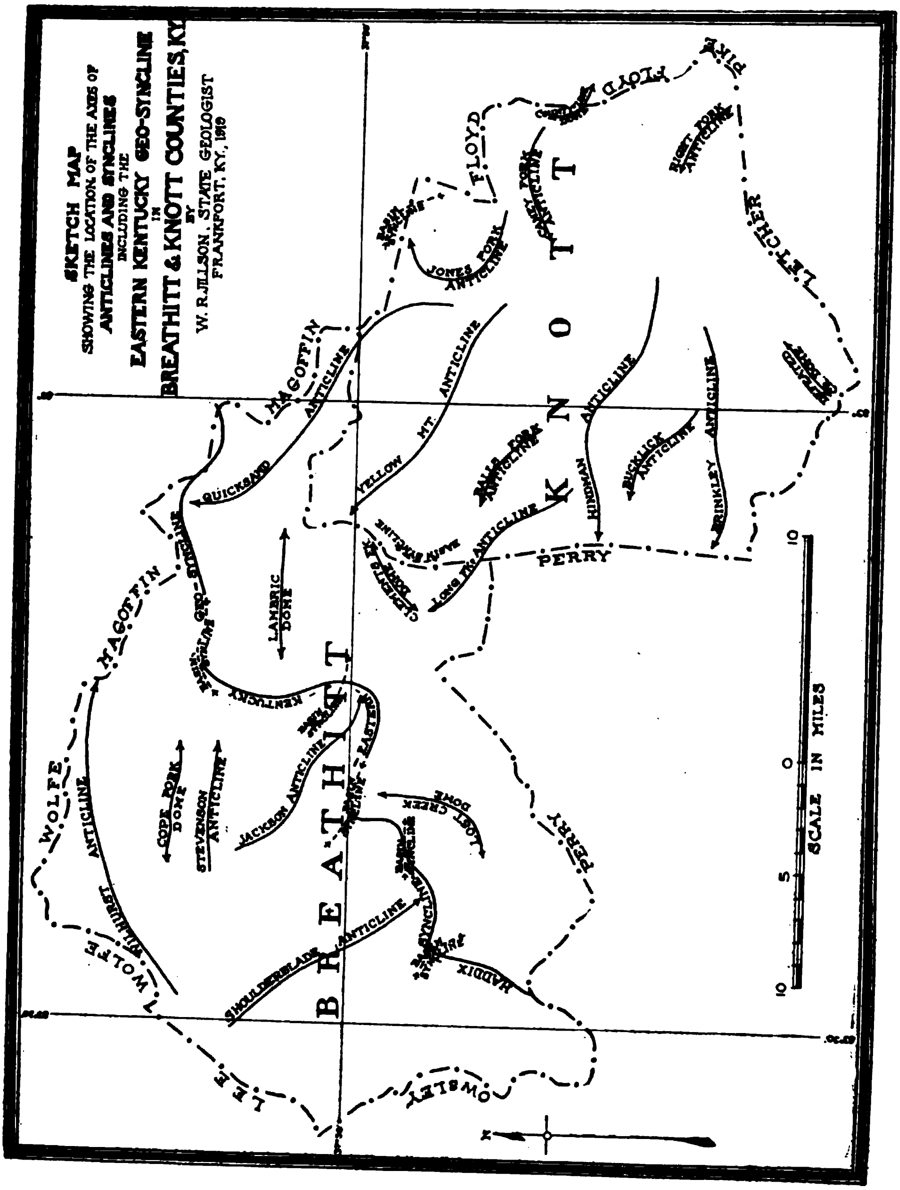
STRUCTURE

General Statement

The structure of Breathitt and Knott counties is thoroughly representative of that found throughout the Eastern Kentucky Coal Fields. Breathitt County is crossed by the Eastern Kentucky Geosyncline, which fact places this area in the structural basin of the eastern portion of this state. Broadly speaking the rock strata of the northwestern part of Breathitt County dip toward the southeast, and the rock strata of southeastern Breathitt County and Knott County dip toward the northwest. The line of the lowest structural elevation in this region is the Haddix Syncline, which bisects Breathitt County and is coincidental with the Eastern Kentucky Geosyncline.

In the accompanying structural maps of Breathitt and Knott counties, by Mr. Iley B. Browning, structural contour or lines of equal elevation above sea level have been used to depict in detail the actual fold in the Kenawha Series of Upper Pottsville Rocks. The key bed used was the flint clay parting of the Fireclay Coal, which in this part of Kentucky is the most dependable horizon for structural work.

A true conception of the stratigraphic-structural geology presupposes a time when, following the deposition of the rock strata of any sedimentary region, all of the beds were essentially flat or horizontal, through restricted areas at least. This of course would be the position water deposited beds would naturally occupy following undisturbed deposition. During the time of the uplift and emergence of all marine sedimentaries when land areas are being formed, many changes from the original horizontal or nearly horizontal position of the strata take place. These changes fall into two distinct structural groups: (1) Folds, and (2) Faults. A fold in sedimentary rocks is much like a fold in layers of cloth or paper. It may either be elongated, in which case it is called an anticline; or somewhat rounded, in which case it is called a dome. In each case this kind of fold resembles an arch or an inverted "U." Down


SKETCH MAP
SHOWING THE LOCATION OF THE AXES OF
ANTICLINES AND SYNCLINES
INCLUDING THE
EASTERN KENTUCKY GEO-SYNCLINE
IN
BREATHITT & KNOTT COUNTIES, KY.
BY
W. R. JILLSON, STATE GEOLOGIST
FRANKFORT, KY., 1919
BREATHITT
KNOTT
MAGOFFIN
FLOYD
PIKE
LETCHER
PERRY
OWSLEY
LEE
WOLFE
QUICKSAND
YELLOW MT. ANTICLINE
JONES FORK ANTICLINE
HINDMAN ANTICLINE
BUCKLICK ANTICLINE
BRINKLEY ANTICLINE
LAMBRIC DOME
COPE FORK DOME
STEVENSON ANTICLINE
JACKSON ANTICLINE
LOST CREEK DOME
SHOULDERBLADE ANTICLINE
HADDIX
WILHURST ANTICLINE
LONG FK. ANTICLINE
SCALE IN MILES
10
5
0
10

horizontal or nearly horizontal position of the strata take place. clines or structural basins. The second great group of structural features are faults, which are simply breaks, more or less perpendicular down through the rock strata, which have been attended by vertical or horizontal displacement. Both folds and faults are the result of crustal stresses and strains, and their varying figures are structural translations of the force expended against the normal strength of the rocks of the deformed area.

In Breathitt and Knott counties the important structural features are those of the folded order. While many small faults may be noted at various points throughout these two counties, none of them has a displacement of over ten feet. Most of the faults have a displacement of a foot or less. Because of this fact they could not be shown to advantage on a structural map with a ten foot contour interval. Their significance is entirely local and is not considered in this area of any special importance to oil or gas accumulation.

Structure of Breathitt County.

Breathitt County occupies a trough position in the structure of Eastern Kentucky. The Haddix Syncline enters the county from the southwest at the point where the Middle Fork of the Kentucky River crosses the Perry County line. It takes a serpentine course to the northeast, leaving Breathitt and passing into Magoffin County on the north headwaters of Hawes' Fork, of Quicksand Creek. The Haddix Syncline in its course passes close to Crockettsville on the Middle Fork of the Kentucky River, Copland and Haddix, on the North Fork, and Rousseau on Quicksand Creek. Generally it crosses and re-crosses the Cumberland Pipe Line, which is essentially in a synclinal position in Breathitt County.

There are four anticlines and three domes of importance in Breathitt County. These are—as indicated on the map—the Willhurst Anticline, in the northwestern part of the county; the Shoulder Blade Anticline, in the western part of the county, between the Middle and North Forks of the Kentucky River; the Jackson and the Stevenson Anticlines, in the central part of the

county; the Cope's Fork Dome, in the northern part of the county, between Frozen Creek and Cope's Fork; the Lambric Dome, in the eastern part of the county, between North and South Quicksand Creeks, near Lambric post office; Clement's Fork Dome, in the eastern part of the county, overlapping the Knott County line; and the Lost Creek Dome, in the southern part of the county, south of Lost Creek post office. Of these structures the Willhurst Anticline, the Shoulder Blade Anticline, the Stevenson Anticline, the Jackson Anticline and the Cope's

BLOWING TAULBEE NO. 3.

This well is on the Wilhurst Anticline, in orthern Breathitt County, and produces 4,750,000 cubic feet of natural gas. It has a rock pressure of 500 pounds. It is the property of the Big Six Oil Co. Photo by W. R. Jillson, 1919.

Fork Dome are on the northwest flank of the Haddix Syncline, and the Lambric Dome, Clement's Fork Dome and the Lost Creek Dome are on the southeastern flank of the Haddix trough.

WILLHURST ANTICLINE

The major axis of this anticline is crescentric from southwest to east and falls from an elevation of 1,180 feet on the North Fork of the Kentucky River to an elevation of 940 feet on the head of Hunting Creek, of Quicksand Creek. The Willhurst Anticline has been drilled on Johnson and Boone Forks of Frozen Creek, on Main Frozen Creek, and on the Sulphur Branch of Clear Fork of Frozen Creek, with a total of twelve wells. Three of these on the Boone Fork produced oil, but in small quantity; three of these produced gas in large quantity; four were dry holes and two were drillings. The gases occupy a high or crestal position on the structure, the oil coming at lower points.

SHOULDER BLADE ANTICLINE

This structure extends southeastward from the Lee County line as a more or less definite structure between the Middle and North Forks of the Kentucky River. It has had but two wells drilled on it, on the headwaters of Twin Creek, a tributary of the Middle Fork of the Kentucky River, and one near Elkatawa, on Caney Creek, a tributary of the North Fork of the Kentucky River. Both of these wells were dry. There is a structural drop on the Shoulder Blade Anticline to the southeast from 1160 feet to 900 feet just southwest of Copland.

JACKSON ANTICLINE

The Jackson Anticline, the major axis of which extends southeastward from a point just east of Jackson to the head of Russell Fork of Troublesome Creek, has had two dry holes drilled on either side of it at very low structural positions. There is a fall in this anticline from an elevation of 1010 feet to an elevation of 840 feet.

STEVENSON ANTICLINE

This anticline lies about two miles south of Cope's Fork Dome, between Frozen Creek and Quicksand Creek. Its major

axis runs almost east and west and falls from an elevation of 1050 feet to 830 feet. It is undrilled.

Haddix Syncline

The Haddix Syncline in Breathitt County is coincident with the Eastern Kentucky Geosyncline. As such it is the line of the lowest structural elevation in this part of the state. Thi syncline is characterized in Breathitt County by a series of five closed basin synclines. These are, progressing from southwest to southeast, (1) the Crockettsville Basin Syncline; (2) the Middle Fork Basin Syncline; (3) the Copland Basin Syncline; (4) the Smith Branch Basin Syncline; and (5) the Rousseau Basin Syncline. These synclinal cups are located from two to four miles from each other and show either two or three closed contours. Their structural depth therefore is between twenty and thirty feet and

BLOWING THE TAULBEE NO. 2.

This well located in northern Breathitt County, on the Wilhurst Anticline is producing 5,750,000 cubic feet of gas with a rock pressure of 500 pounds. It is owned by the Big Six Oil Co. and has ot yet been commercialized. Photo by W. R. Jillson. 1919.

in this sense they are exactly comparable to the three domes in Breathitt County, whose closed structural elevation is about the same. The Haddix Syncline enters Breathitt County from Perry at an elevation of 860 feet and passed into Magoffin at an elevation of 830 feet. Its lowest point in Breathitt County is found at Rousseau, where it is only 780 feet above sea level.

Cope's Fork Dome

This structure lies between Clear Creek and Cope's Fork of Frozen Creek. It is quite elliptical in figure and exhibits a closure to the west of 20 feet. The structural drop to the southeast is sharp and the rise to the west and northwest is gradual. One well has been drilled on Cope's Fork which has produced gas. It was drilled in a rather low position on the southern flank.

Lambric Dome

This structure lies on the southeast side of the Haddix Syncline, between North and South Quicksand Creek. It is in reality a doming anticline, the closure to the east only amounting to about 15 feet. Pronounced synclinal areas finger into it from both the north and the south to such an extent as to suggest that it is in reality an arrested dome of much larger proportions. It is undrilled.

Lost Creek Dome

The Lost Creek Dome shows a long major axis in a north and south direction, with a closure of 20 feet to the east. This structure, with a highest elevation of 900 feet, is essentially in the bottom of the Eastern Kentucky Geosyncline, since it is only about 35 feet above the nearest point of the axis of the Haddix Syncline. It is undrilled.

The Structure of Knott County.

The structural features of Knott County are nearly as well defined as those of Breathitt County. Knott County is entirely located on the southeastern flank of the Eastern Kentucky Geosyncline. At no point is it therefore as low structurally as is Breathitt County. The normal dip is to the northwest. Within

general limits this dip is uniform, but is somewhat lower and flatter to the northwest of Hindman, and considerably higher and steeper to the southeast of the same town. In general the dip of this section averages betwen 15 and 25 feet to the mile.

In Knott County there are five large and four small anticlines; two domes and two basin synclines. The large anticlines are (1) Quicksand Anticline; (2) Yellow Mountain Anticline; (3) Long Fork Anticline; (4) Hindman Anticline; and (5) Brinkley Anticline. The smaller anticlines are (1) Jones' Fork Anticline; (2) Right Fork Anticline; (3) Bucklick Anticline; and (4) Caney Fork Anticline. The domes are (1) County Line Dome, and (2) Defeated Creek Dome. The synclines are (1) Buckhorn Basin Syncline and (2) Rock Fork Basin Syncline. The detail of these structures is as follows:

Quicksand Anticline

The Quicksand Anticline is the northernmost anticlinal structure in Knott County. It is in reality also a Breathitt County structure, but is discussed with the Knott County structures since it has its inception at an elevation of 1090 feet on Rock Fork of Right Beaver Creek, in Knott County. Its major axis runs to the northwest in the form of the letter "S," passing into Breathitt County at the head of Middle Fork of Quicksand, where it swings around to the north, crosses Hawes' Fork sand, where it swings around to the north, crosses Hawes' Fork and meets the Haddix Syncline at an elevation of 850 feet. Its structural fall is 240 feet. It is a pronounced structure throughout its course, but shows a decided tendency toward terracing or doming on the headwaters of Spring Fork of Quicksand Creek. One dry hole has been drilled on the head of it, in Knott County, on the headwaters of Saltlick Creek.

Yellow Creek Anticline

The Yellow Mountain Anticline parallels in a measure the Quicksand Anticline, about three or four miles to the south. Its highest elevation is 1120 feet, found on the ridge beetween Jones' Fork of Right Beaver and Ball's Fork of Troublesome. Its major axis extends toward the northwest and is located at an elevation of 880 feet. The structure of this anticline is the same as that of the Quicksand Anticline. This structure is undrilled.

Lost Creek Anticline

The Lost Creek Anticline rises about five or six miles south of the Yellow Mountain Anticline, at an elevation of 990 feet, on Ball's Fork. It drops to an elevation of 880 feet, on Long Fork of the Troublesome Creek, just south of Clement's Fork Dome. It is undrilled.

Hindman Anticline.

The Hindman Anticline starts at an elevation of 1320 feet at the head of Caney Fork of Right Beaver and extends in a serpentine course downward to the west and northwest to an elevation of 920 feet, exhibiting a fall of 400 feet. This structure is quite pronounced southwest of Hindman, but is less pronounced to the northwest. It is undrilled.

Brinkley Anticline

The Brinkley Anticline rises in the region between the Right Fork of Troublesome Creek and Carr's Fork, about one mile south of Brinkley Post Office, at an elevation of 1250 feet. Its major axis extends almost due west, the structure disappearing on Lost Creek, near the Perry County line, at an elevation of 970 feet. The structural fall of this anticline is therefore 280 feet. In its easternmost part this anticline is pronounced, but its configuration is not as well defined to the west of Lost Creek.

SMALLER ANTICLINES

Jones' Fork Anticline.

The Jones' Fork Anticline rising on the Bear Branch of Jones' Fork, in the northeastern part of Knott County, extends in a crescentric form to the north of Rock Creek, where it descends to the Floyd County line. Its highest point, which is found on Bear Branch, is 1140 feet, and its lowest point, which is found on Rock Creek, is 1050 feet, giving a structural fall of 90 feet. The lower part of Jones' Fork Anticline has been drilled at a umber of points and shows production in the Potts-

ville. Since, however, the writer considers the production associated with adjoining structures, further reference to production on this structure will be omitted.

Caney Fork Anticline

This structure rises on Sly Branch of the Right Fork of Beaver Creek and extends in an open crescent to the northwest and west, crossing Big Branch of Caney Fork. Its highest point on Sly Branch is 1310 feet and its lowest point, which is on Gibson Creek, of Caney Fork, is 1200 feet, giving it a structural fall of 110 feet. This structure has been drilled, with a dry hole on Caney Fork, just above Big Branch.

Right Fork Anticline

The Right Fork Anticline is very small and is found in the southeastern part of Knott County, on the headwaters of Right Fork of Beaver Creek, its highest point occurring within a half mile of the head of Puncheon Branch, at an elevation of 1660 feet. Its lowest point is a mile below Ivan, on Bill D. Branch of Right Beaver Creek. The elevation here is 1490 feet, giving it a structural fall of 170 feet. This structure has never been drilled.

Bucklick Anticline

This small structure is in reality a north finger of the Brinkley Anticline. It finds its inception at an elevation of 1140 feet, near the head of Elklick Fork on Young's Fork of Lost Creek. Its major axis extends to the northwest in the ridge between Clear Creek of Troublesome Creek. Its lowest point occurs about one mile south of the Emmalena Post Office, at an elevation of 1000 feet, giving it a structural fall of 140 feet. It is undrilled.

DOMES

County Line Dome

This small dome is located in the eastern portion of Knott County and overlaps into the south-nipple of Floyd county. It is found on the head of the Old House Branch of Right Beaver

Creek, and is in total area not more than a mile square. Three ten feet contours close about it, giving it a structural height of slightly more than thirty feet. This structure is undrilled.

Defeated Creek Dome

This structure is located in the southernmost portion of Knott County, one-half mile south of Cody Post Office, on Defeated Creek, a headwater tributary of Carr's Fork. This structure is a small one comparable in size to the County Line Dome to the northeast. With two closed contours, it shows but slightly more than 20 feet in height. It is undrilled.

BASIN SYNCLINES

Buckhorn Basin Syncline.

The Buckhorn Basin Syncline. the most pronounced cup syncline in Knott County, is found in the northwestern portion of the county, adjoining the Breathitt County line, on Buckhorn Creek. It shows two closed contours and is about 20 feet in depth. No wells have been drilled in this syncline.

Rock Fork Basin Syncline

The Rock Fork Basin Syncline is located on Rock Creek, of Right Beaver, and lies partly in Knott and partly in Floyd counties. It is a rather large flat elongated synclinal basin, showing only one closed ten-foot contour. A considerable amount of drilling has been done in this structural depression and with success, oil production being secured from the Beaver, Horton and Pike, of the Pottsville, and Maxon of the Mauch Chunk. Gas production in small amounts has been secured from all of the above named sands and in addition from the underlying Big Injun, of the Mississippian System. The development in this section of Knott and Floyd counties is old, the first well having been drilled in but a few miles to the north of the Knott County line, on Right Beaver Creek, at the mouth of Saltlick in Floyd County, by Louis H. Gormley, in 1891. Production was secured in this original well, the Howard Purchase No. 1, in the Lower

Pottsville. Since this many wells have been drilled in this vicinity, extending the pool so as to cover practically all of this synclinal basin. Though an old field, new drilling in this vicinity has resulted in bringing in new production apparently as good as that of the original wells, many of which are still producing, though not nearly so largely as formerly.

SUMMARY

It is difficult in as large an area as that covered by Breathitt and Knott counties to pick out the areas which may be expected to produce. It is also equally as hard to point out the unfavorable sections. The amount of drilling which has been done in these two counties demonstrates, however; these facts. Production, either of oil or gas, is usually found associated with anticlinal or doming structure. This is true in northwestern Breathitt County and again in eastern Knott County. It is not true, however, in connection with the oil production secured on Rock and Jones' Fork of Right Beaver, at which point the oil production is synclinal, as interpreted from surface observations. In Breathitt County a large number of dry holes have been drilled off of structure, and a very few have been drilled on structure. In the same county the wells which have been drilled in absolutely synclinal or basin synclines have not shown to date production as has the Rock Fork Basin Syncline of Knott and Floyd. However, a very small number of wells have been drilled in the basin synclines of Breathitt County, and it may be pointed out that the possibility of the Pottsville Sands in this section have not yet either been exhausted or thoroughly tested. Generally the structure of Breathitt County is more pronounced and in this same measure more favorable to oil and gas accumulation than it is in Knott. On the other hand, the structure in Knott County rises to an elevation 500 feet higher than the highest contour in Breathitt County and for this reason it may be expected to draw from a larger area. The development in Knott County is in its infancy, only two localities having received any attention at all. These are the Rock and Jones' Fork sections, and the Right Beaver section. In both of these localities production in the Pottsville and Mauch Chunk has been secured. A dry well was drilled several years ago on Mill

Branch of Ball's Fork, north of Hindman, which did not reach the Big Lime of the Mississippian System. For this reason the fuller productive possibilities of the underlying sands in this section of the state are unknown. A large number of the anticlines mapped and described in this report are in fact nothing more than low plunging folds without the slightest indication of closure of contours. This kind of a structure is not considered more favorable for oil and gas accumulation than a single Monocline. The very pronounced anticlines like the Willhurst, and the closed structures like the Copes Fork Dome should, however, receive careful drilling considerations as they may be looked to for both oil and gas production.

First Published October, 1919.

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First Published October, 1919.

XI.

THE PRODUCTION OF COAL IN KENTUCKY.

INTRODUCTORY

The unparalleled expansion of the coal mining industry in Kentucky during the past decade has established figures of production which are little short of amazing. This is especially true of the Eastern Coal Field, which may be said to have received during the latter part of this decade, its principal development. The total production of coal in Kentucky for the year 1906 was 9,653,647 short tons. The total production of coal in Kentucky

A UNIT COAL MINE ON BEAVER CREEK

The view shows the main entry to the mine on the hillside, the tipple, power plant and office in the middle foreground, and a few of the miners' houses at the bottom of picture. Photo by W. R. Jillson. April, 1919.

for the year 1918 was 31,530,442 short tons, an annual growth of 1,824,000 shorts. or something over 200 per cent. Back of and responsible for the tremendous increase in coal production in this state is a correspondingly widening interest and faith in the coal resources of Kentucky. The following figures of production have been compiled from all available sources, including the Mineral

Resources of the United States Geological Survey, and the annual publications of the Kentucky State Department of Mines.

A DOUBLE TIPPLE

At the head of small creeks and branches in Eastern Kentucky coal is most advantageously worked by use of a bridging tipple, as shown above. Photo by W. R. Jillson. April, 1918.

to meet a growing demand for summary production data and allied information on this important mineral resource.

Statistics of Production

Although much coal was mined and sold in Kentucky in the early part of the nineteenth century, the most of it found domestic consumption within the state and the greater portion was used by the miners themselves, who were mostly farmers, for their own use. The first export coal from Kentucky occurred in the year 1828 and with this year the beginning of the industry on a commercialized basis was established. Since 1828 the growth in the production of coal has been steady and consistent with the character and location of the principal coal fields. During the early part of the nineteenth century the principal coal areas in Kentucky could not be commercialized because of the lack of railroad or other transportation facilities. This retarded state of affairs would not allow the coal which could have been produced to compete with that of other more favorably located

THE PLACE OF PERPETUAL NIGHT

The head of a side entry in an Eastern Kentucky coal mine. The upper bench has been partly loaded.

north, northeastern and northwestern fields in adjoining states. The era of enlargement and extension of the railroad system in Kentucky is directly reflected in the increasd production of coal in this state, and one of the very best examples of the applicableness of this statement is the growth of the coal production in the Elkhorn and other headwater coal fields of the Southeastern District. The figures of coal production for 1828 to 1918, inclusive, have been compiled and are presented herewith. These statistics show that in eight years, from 1911 to 1918, there were produced in Kentucky 176,105,234 short tons of coal. From 1828 to 1910, inclusive, a total of eighty-two years, there was produced 157,971,800 short tons of coal. By subtraction then it is seen that the last eight years has produced an excess of 18,133,434 short tons of coal over the preceding eighty-two years. The figures of production are as follows:

COAL ENROUTE TO THE CONSUMER

The railroads play a very important part in the coal industry. The run of each mine must be moved each day to insure continued production. The above view was taken on the headwaters of Beaver Creek, Floyd County, Kentucky. Photo by W. R. Jillson, 1918.

PRODUCTION OF COAL IN KENTUCKY
1828 TO 1918.

Year	No. Short Tons
1828	328
1829	2,000
1830	2,000
1831	2,100
1832	2,500
1833	2,750
1834	5,000
1835	6,000
1836	8,000
1837	10,000
1838	11,500
1839	16,000
1840	23,527
1841	35,000
1842	50,000
1843	60.000
1844	75,000

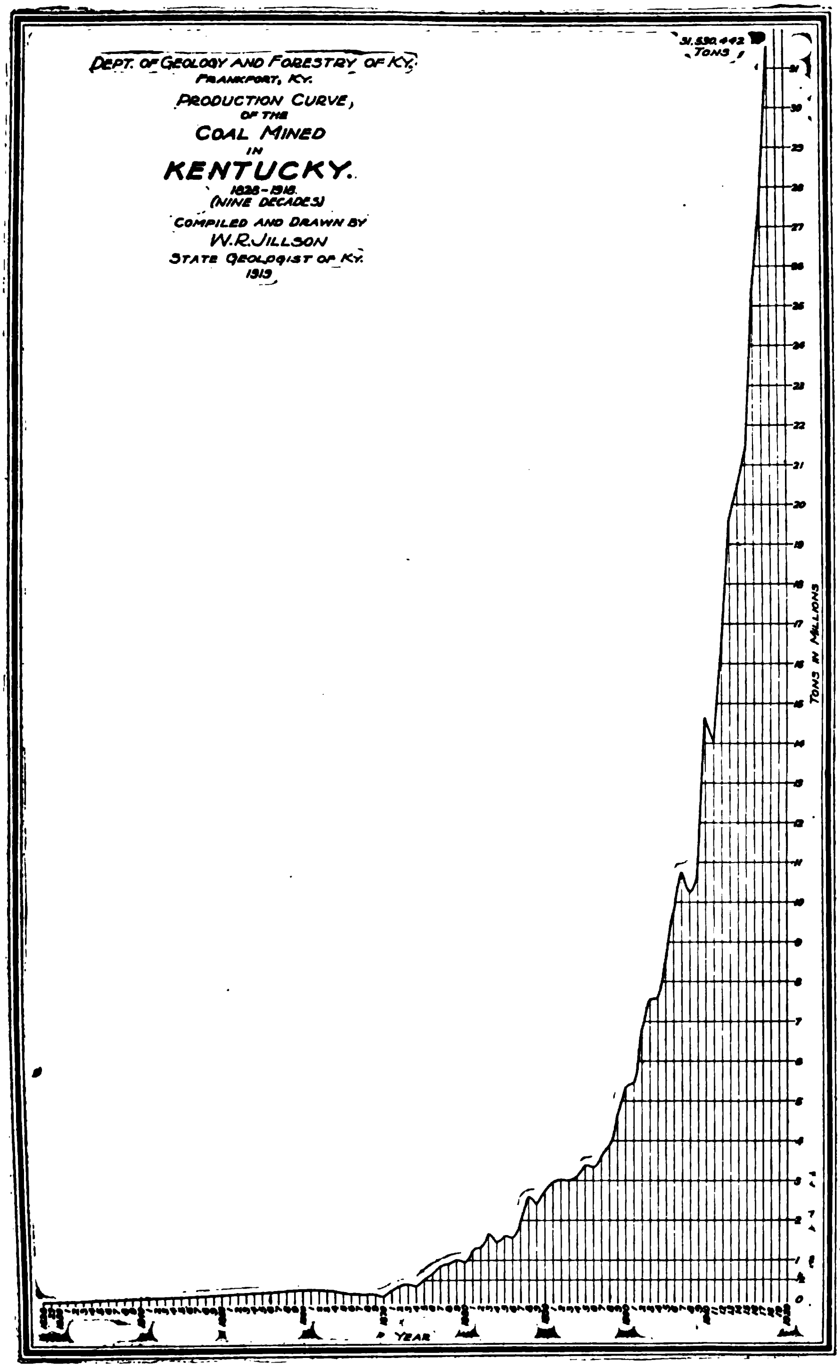
Year	No. Short Tons
1845	100,000
1846	115,000
1847	120,000
1848	125,000
1849	140,000
1850	150,000
1851	160,000
1852	175,000
1853	180,000
1854	190,000
1855	200,000
1856	215,000
1857	240,000
1858	250,000
1859	275,000
1860	285,760
1861	280,000
1862	275,000
1863	250,000
1864	250,000
1865	200,000
1866	180,000
1867	175,000
1868	160,000
1869	160,000
1870	150,582
1871	250,000
1872	380,800
1873	400,000
1874	360,000
1875	500,000
1876	650,000
1877	850,000
1878	900,000
1879	1,000,000
1880	946,288
1881	1,232,000
1882	1,300,000
1883	1,300,000
1883	1,650,000
1884	1,550,000
1885	1,600,000
1886	1,550,000
1887	1,933,185
1888	2,570,000

1889	2,399,755
1890	2,701,496
1891	2,916,069
1892	3,025,303
1893	3,007,179
1894	3,111,192
1895	3,357,770
1896	3,333,478
1897	3,602,097
1898	3,887,908
1899	4,607,255
1900	5,328,964
1901	5,469,986
1902	6,766,984
1903	7,538,032
1904	7,576,482
1905	8,432,523
1906	9,653,647
1907	10,753,124
1908	10,246,533
1909	10,697,384
1910	14,623,319
1911	14,049,703
1912	16,490,521
1913	19,616,600
1914	20,382,763
1915	21,361,674
1916	25,393,997
1917	27,809,976
1918	31,530,442
Total production 1829-1918	365,077,034

Kentucky Coal Production

In Two Groups.

1911 to 1918, inclusive (eight years)	176,105,234
1828 to 1910, inclusive(eighty-two years)	157,971,800
Excess	18,133,434



DEPT. OF GEOLOGY AND FORESTRY OF KY.
FRANKFORT, KY.
PRODUCTION CURVE,
OF THE
COAL MINED
IN
KENTUCKY.
1828-1918.
(NINE DECADES)
COMPILED AND DRAWN BY
W.R.JILLSON
STATE GEOLOGIST OF KY.
1919
31,530,442
TONS
TONS IN MILLIONS
YEAR

A DOUBLE ENTRY MINE

The view is in Eastern Kentucky on the head of Left Beaver Creek, in Floyd County. A loaded train motor drawn is seen leaving the mine.

Coal Production by Decades

The total coal production figures by decades during the past ninety years for this state are quite as interesting, if not more informative, than those of the separate years. The summary of production for the eight decades, from 1828 to 1907, inclusive, is 122,404,564 short tons. The summary of production for the ninth decade, from 1908 to 1917, inclusive, is 180,672,470 short tons, giving an increase in production in the ninth decade over that of the total production for the preceding eight decades of 58,267,906 short tons. Coal production figures by decades are as follows:

AN EASTERN KENTUCKY COAL TOWN

The view shows the miners' houses only, the business section being loacted further up the creek. Photo by W. R. Jillson, 1918.

1828 to 1837	40,678
1838 to 1847	606,027
1848 to 1857	1,775,000
1858 to 1867	2,420,760
1868 to 1877	3,861,382
1878 to 1887	13,661,473
1888 to 1897	30,024,339
1898 to 1907	70,014,905
Total eight decades	122,404,564
1908 to 1917 (ninth decade)	180,672,470
1828 to 1907 (eight decades)	122,404,564
Excess	58,267,906
Total production (1828-1917)	334,077,034

Coal Produced in Kentucky in 1915 and 1916.

1915

County	Loaded at mines for shipment (net tons).	Sold to local trade and used by employees (net tons).	Used at mines for steam and heat (net tons).	Made into coke at mines (net tons).	Total quantity (net tons).	Total value	Average value per ton.	Number of employees.	Average number of days worked.
Eastern District:									
Bell	2,210,498	47,769	48,564		2,306,831	$2,414,790	$1.05	3,551	209
Boyd	73,211	2,871	1,918		78,000	65,872	.84	164	191
Breathitt, Greenup, Knott, Lawrence and Lee	67,401	6,218	973		74,592	77,541	1.04	114	207
Carter	65,152	3,649	14,612		83,413	89,669	1.08	151	179
Floyd	510,059	26,161	8,851		545,071	566,174	1.04	711	178
Harlan	1,390,346	12,312	15,677	308,463	1,726,798	1,827,144	1.06	1,496	226
Jackson and Pulaski	1,837	3,581			5,418	6,895	1.27	17	147
Johnson	928,645	17,897	28,922		975,464	1,257,332	1.30	1,282	221
Knox	746,796	5,043	15,874		767,713	815,986	1.06	1,480	195
Laurel	84,302	55	779		85,136	84,896	.99	229	143
Letcher	2,204,129	12,234	12,971		2,229,334	2,656,628	1.19	2,159	296
McCreary	566,737	1,781	987		569,535	642,244	1.13	970	173
Morgan	51,410	5,762	1,643		58,815	128,450	2.18	202	254
Perry	532,998	2,261	12,703		547,962	615,690	1.12	724	242
Pike	2,648,211	37,043	50,913	94,072	2,830,239	2,689,825	.95	2,928	211
Whitley	776,450	7,684	21,312		805,446	1,068,934	1.33	1,782	162
	12,858,212	192,224	2[illegible]6,[illegible]9	402,535	13,689,770	15,018,120	1.10	17,970	2[illegible]5
Western District:									
Christian and McLean	92,356	350	55[illegible]		93,256	85,503	.92	184	176
Daviess	6,000	35,320	1,458		42,778	41,157	.9[illegible]	67	[illegible]
Hancock	1,000	3,000			4,000	5,425	1.36	12	190
Henderson	103,787	52,896	10,021		166,704	184,834	1.11	261	195
Hopkins	2,129,808	49,568	97,197	55,570	2,332,143	1,843,827	.79	2,737	149
Muhlenberg	2,159,213	22,559	70,273		2,252,045	1,844,506	.83	3,451	113
Ohio	463,168	33,906	22,746		519,820	417,373	.80	1,108	111
Union	653,818	47,679	40,613		742,110	708,440	.95	776	213
Webster	1,354,030	19,214	35,756		1,409,000	1,172,929	.83	1,414	176
	6,963,180	264,492	258,61[illegible]	55,570	7,541,856	6,303,194	.84	9,990	151
Small mines		130,048			130,048	171,894	1.32		
Grand total	19,821,392	586,864	495,31[illegible]	458,105	21,361,674	21,494,038	1.01	27,960	183

Coal Produced in Kentucky in 1915 and 1916—Continued.

1916

County	Loaded at mines for shipment (net tons).	Sold to local trade and used by employees (net tons).	Used at mines for steam and heat (net tons).	Made into coke at mines (net tons).	Total quantity (net tons).	Number of Employees. Under-ground.	Surface	Total	Average number of days worked.
Eastern district:									
Bell	2,182,454	27,859	34,229		2,244,542	3,308	621	3,929	208
Boyd	74,179	9,229	2,173		85,581	139	49	188	232
Breathitt, Greenup, Knott, Lawrence and Lee	32,912	3,700	600		37,212	63	20	83	144
Carter	119,258	3,983	336		123,577	145	31	176	238
Floyd	851,158	8,149	14,146		873,453	772	157	929	197
Harlan	1,879,589	18,155	15,673	300,811	2,214,228	1,651	435	2,086	219
Jackson and Pulaski	4,985	5,023	156		10,164	16	7	23	200
Johnson	932,808	12,210	30,468		975,486	974	255	1,229	240
Knox	775,426	13,437	14,661		803,524	1,110	261	1,371	214
Laurel	86,803	120	715		87,638	200	18	218	165
Letcher	3,627,815	16,555	27,066		3,671,436	3,002	304	3,306	274
McCreary	654,340	9,950	1,000		665,290	898	93	991	256
Morgan	47,573	1,092	62		48,727	149	36	185	258
Perry	973,760	4,753	13,719		992,232	846	261	1,107	224
Pike	3,285,961	128,891	52,850	289,225	3,756,927	2,705	608	3,313	252
Whitley	869,108	13,650	22,670		905,428	1,519	269	1,788	197
	16,398,129	276,756	230,554	590,036	17,495,475	17,497	3,425	20,922	231
Western district:									
Christian	103,875	1,100	3,000		107,975	170	24	194	235
Daviess		59,335	520		59,855	63	12	75	240
Henderson	111,334	65,771	8,643		185,748	277	45	322	192
Hopkins	2,356,617	104,260	99,117	62,531	2,622,525	2,260	415	2,675	179
McLean	54,160	4,020	200		58,380	63	11	74	190
Muhlenberg	1,962,127	28,814	45,878		2,036,819	3,219	359	3,578	140
Ohio	428,339	33,966	22,635		484,940	1,073	105	1,178	112
Union	542,538	74,878	42,660		660,073	697	141	838	163
Webster	1,515,302	23,402	31,534		1,570,238	1,182	184	1,366	209
	7,074,292	395,546	254,187	62,531	7,786,556	9,004	1,296	10,300	162
Small mines*	1,000	110,966			111,966				
Grand total	23,473,421	783,268	484,741	652,567	25,393,907	26,501	4,721	31,222	208

*Includes Hancock County.

VALUE OF COAL PRODUCED IN KENTUCKY IN 1916.

County	Loaded at mines for shipment (net tons).	Sold to local trade and used by employees (net tons).	Used at mines for steam and heat	Made into coke at mines	Total value	Average value per ton
Eastern District:						
Bell	$2,907,611	$39,422	$34,253		$2,981,306	$1.33
Boyd	88,282	10,792	2,850		101,924	1.19
Breathitt, Greenup, Knott, Lawrence and Lee	46,590	4,875	875		52,340	1.41
Carter	171,229	5,175	361		176,765	1.43
Floyd	1,148,198	9,763	13,610		1,171,571	1.31
Harlan	2,495,767	31,995	18,991	$300,814	2,847,567	1.29
Jackson and Pulaski	7,929	5,525	140		13,594	1.34
Johnson	1,471,493	17,409	40,077		1,528,979	1.57
Knox	984,408	17,053	14,080		1,015,451	1.26
Laurel	93,122	130	745		93,997	1.07
Letcher	4,651,497	22,927	33,604		4,708,028	1.28
McCreary	660,470	13,978	2,000		676,448	1.02
Morgan	100,393	2,585	91		103,069	2.12
Perry	1,358,730	5,819	16,247		1,380,796	1.39
Pike	3,573,653	126,934	47,284	267,223	4,015,094	1.07
Whitley	1,349,174	25,624	29,184		1,403,982	1.55
	21,108,546	340,026	254,392	568,037	22,271,001	1.27
Average value per ton	1.29	1.23	1.10	.96	.127	
Western District:						
Christian	137,432	1,165	1,500		140,097	1.30
Daviess		76,638	568		77,206	1.29
Henderson	119,889	96,026	8,909		224,824	1.21
Hopkins	2,228,838	89,999	88,574	58,779	2,466,190	.94
McLean	70,584	4,040	200		74,824	1.28
Muhlenberg	2,083,637	33,665	36,172		2,153,474	1.06
Ohio	382,916	41,925	7,303		432,144	.89
Union	566,434	98,925	33,262		698,621	1.06
Webster	1,435,125	23,298	28,932		1,487,355	.95
	7,024,855	465,681	205,420	58,779	7,754,735	1.0
Average value per ton	.99	1.18	.81	.94	1.00	
Small mines*	1,750	165,561			167,311	1.49
Grand total	28,135,151	971,268	459,812	626,816	30,193,047	1.19
Average value per ton	1.20	1.24	.95	.96	1.19	

*Includes Hancock County.

Coal Produced in Kentucky, 1913-1916, in Net Tons.

COUNTIES	1913	1914	1915	1916	Increase or decrease, 1916
Eastern District:					
Bell	2,488,538	2,579,011	2,306,831	2,244,542	— 62,289
Boyd	131,208	92,882	78,000	85,581	+ 7,581
Breathitt, Greenup, Lawrence and Lee	105,396	[1] [2] 113,242	[2] 74,592	[2] 37,212	— 37,380
Carter	110,595	84,475	83,413	123,577	+ 40,164
Floyd	445,949	524,923	545,074	873,453	+ 328,379
Harlan	750,267	1,264,066	1,726,798	2,214,228	+ 487,430
Johnson	861,189	935,630	975,464	975,486	+ 22
Knox	961,492	904,684	767,713	803,524	+ 35,811
Laurel	196,569	101,205	85,136	87,638	+ 2,502
Letcher	[1]	1,427,626	2,229,334	3,671,436	+ 1,442,102
McCreary	625,101	586,541	569,535	665,290	+ 95,755
Morgan	90,346	76,028	58,815	48,727	— 10,088
Perry	24,953	221,012	347,962	992,262	+ 444,300
Pike	2,124,041	2,653,315	2,830,239	3,756,927	+ 926,688
Whitley	1,015,370	854,019	806,446	905,428	+ 99,982
Other countries[3]	1,107,833	3,100	5,418	[3] 10,164	+ 4,746
	11,038,847	12,421,759	13,689,770	17,495,475	+ 3,805,705
Western District:					
Christian	69,525	[4] 83,905	[4] 93,256	[4] 107,975	+ [4] 73,099
Daviess	48,543	47,538	42,778	59,855	+ 17,077
Hancock	6,280	7,000	4,000	[5]	[5]
Henderson	220,582	161,066	166,704	185,748	+ 19,044
Hopkins	2,534,821	25,551,720	2,332,143	2,622,525	+ 290,382
McLean	83,329	[4]	[4]	58,380	[4]
Muhlenberg	2,633,271	2,265,153	2,232,045	2,036,819	— 195,226
Ohio	775,545	660,273	519,820	484,940	— 34,880
Union	690,968	585,743	742,110	660,076	— 82,034
Webster	1,394,663	1,475,790	1,400,000	1,570,238	+ 161,238
	8,457,527	7,838,188	7,541,856	7,786,556	+ 248,700
Small mines	120,226	122,816	130,048	[5] 111,966	— 22,082
Grand total	19,616,600	20,382,763	21,361,674	25,393,997	+ 4,032,323
Total value	$20,516,749	$20,852,463	$21,494,008	$30,193,047	+ $8,699,039

[1]No production in Greenup County.
[2]Includes Knott County.
[3]Other counties include Clay, Letcher and Pulaski in 1913; Clay, Pulaski and Rockcastle in 1914; Jackson and Pulaski in 1915 and 1916.
[4]Christian and McLean counties combined.
[5]Hancock County included in small mines.

The comparative output of the various coal producing counties in Kentucky for the calendar years 1917 and 1918, is as follows:

Calendar Year 1917	Tons	Calendar Year 1918	Tons
Pike	3,860,919	Pike	4,532,934
Letcher	3,627,102	Fletcher	3,348,326
Muhlenberg	3,230,854	Muhlenberg	3,623,019
Hopkins	3,037,748	Hopkins	2,830,354
Bell	2,063,459	Bell	2,292,755
Harlan	2,049,469	Harlan	3,176,856
Perry	1,616,557	Perry	2,201,178
Webster	1,318,654	Webster	1,464,508
Union	963,559	Union	961,142
Johnson	959,958	Johnson	869,932
Ohio	877,206	Ohio	1,244,257
Floyd	819,206	Floyd	1,004,631
Whitley	813,563	Whitley	780,872
McCreary	692,097	McCreary	754,316
Knox	690,246	Knox	720,114
Henderson	254,148	Henderson	393,736
Laurel	225,359	Laurel	393,087
Carter	152,401	Carter	187,739
McLean	127,730	McLean	174,321
Boyd	107,145	Boyd	110,561
Morgan	66,476	Morgan	51,103
Christian	60,719	Christian	85,861
Daviess	57,839	Daviess	42,871
Lawrence	38,272	Lawrence	52,430
Breathitt	37,982	Breathitt	169,087
Lee	26,074	Lee	36,650
Jackson	13,999	Jackson	9,124
Clay	12,075	Clay	12,333
Hancock	9,160	Hancock	6,245
	27,809,976		31,530,442

A BUCKETT TIPPLE

The view is on the headwaters of the Russell Fork of the Big Sandy River, in Pike County. Many coal properties on the opposite side of the river from the railroad are now being operated in this way. Photo by W. R. Jillson. May, 1919.

A MORGAN COUNTY CANNEL COAL MINE

Kentucky is famous for its production of high grade cannel coal and some of the best grades of this kind of coal comes from Morgan County. Floyd, Pike, Breathitt, Perry, Knox and several other counties also produce cannel coal. Photo by W. R. Jillson. 1918.

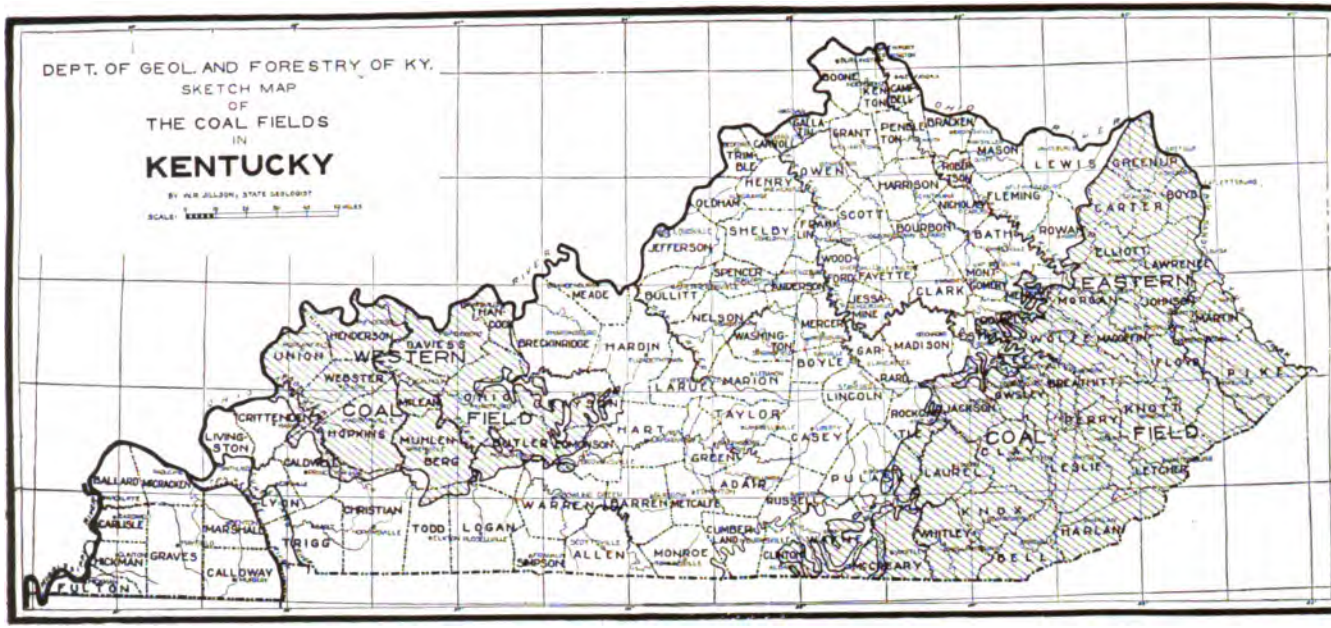
Coal Production by Districts

The production figures for the Eastern and Western Coal Fields during the past three years is as follows:

Field	1916	1917	1918
Western	7,727,428	9,937,617	....
Eastern	17,565,339	17,872,359	....

The 1917 coal production by counties in the three districts, Western, Southeastern and Northeastern, is as follows:

WESTERN DISTRICT	Tons.
Christian (incomplete)	60,719
Daviess	57,839
Hancock	9,160
Henderson	254,148
Hopkins	3,037,748
McLean	127,730
Muhlenberg	3,230,854
Ohio	887,206
Union	963,359
Webster	1,318,654
	9,937,617
SOUTHEASTERN DISTRICT—	
Bell	2,063,459
Clay	12,075
Harlan	2,049,469
Knox	690,246
Laurel	225,359
McCreary	692,097
Whitley	813,563
	6,546,268
NORTHEASTERN DISTRICT—	
Boyd	107,145
Breathitt	37,982
Carter	152,401
Floyd	819,206
Jackson	13,999
Johnson	959,958
Lawrence	38,272
Lee	26,074
Letcher	3,627,102
Morgan	66,476
Perry	1,616,557
Pike	3,860,919
	11,326,091


DEPT. OF GEOL. AND FORESTRY OF KY.
SKETCH MAP
OF
THE COAL FIELDS
IN
KENTUCKY
WESTERN
COAL
FIELD
EASTERN
COAL
FIELD
OHIO
RIVER
BOONE
KENTON
CAMPBELL
GALLATIN
GRANT
PENDLETON
BRACKEN
MASON
LEWIS
GREENUP
BOYD
CARTER
CARROLL
TRIMBLE
HENRY
OWEN
HARRISON
ROBERTSON
FLEMING
ROWAN
ELLIOTT
LAWRENCE
OLDHAM
SHELBY
FRANKLIN
SCOTT
BOURBON
NICHOLAS
BATH
JEFFERSON
SPENCER
ANDERSON
WOODFORD
FAYETTE
CLARK
MONTGOMERY
MORGAN
JOHNSON
MARTIN
MEADE
BULLITT
NELSON
WASHINGTON
MERCER
JESSAMINE
MADISON
WOLFE
MAGOFFIN
FLOYD
PIKE
HANCOCK
BRECKINRIDGE
HARDIN
BOYLE
GARRARD
BREATHITT
HENDERSON
DAVIESS
MARION
LINCOLN
JACKSON
KNOTT
UNION
WEBSTER
McLEAN
LARUE
TAYLOR
ROCKCASTLE
OWSLEY
PERRY
CRITTENDEN
HOPKINS
MUHLENBERG
BUTLER
EDMONSON
HART
CASEY
CLAY
LIVINGSTON
CALDWELL
GREEN
PULASKI
LAUREL
LESLIE
LETCHER
BALLARD
McCRACKEN
LYON
ADAIR
RUSSELL
KNOX
HARLAN
CARLISLE
MARSHALL
CHRISTIAN
TODD
LOGAN
WARREN
BARREN
METCALFE
CUMBERLAND
WAYNE
WHITLEY
BELL
HICKMAN
GRAVES
TRIGG
SIMPSON
ALLEN
MONROE
CLINTON
McCREARY
CALLOWAY
FULTON

Statistics of Gains and Losses by Districts—1917

	Tons
Western District, gain	2,210,189
Northeastern District, gain	672,184
	2,882,373
Southeastern District, loss	365,164
Net gain	2,517,209

Statistics of Gains and Losses by Counties—1917

WESTERN DISTRICT—	Gain	Loss
Christian		41,349
Daviess	17,028	
Hancock		1,340
Henderson	84,576	
Hopkins	431,936	
McLean	55,248	
Muhlenberg	1,214,995	
Ohio	405,596	
Union	300,593	
Webster		257,094
	2,509,972	299,783
Less	299,783	
Net gain	2,210,189	

SOUTHEASTERN DISTRICT—	Gain	Loss
Bell		173,881
Clay	12,075	
Harlan		155,084
Knox		81,439
Laurel	148,038	
McCreary	19,347	
Whitley		134,220
	179,460	544,624
Less		179,460
Net loss		365,164

NORTHEASTERN DISTRICT—	Gain	Loss
Boyd	34,706	
Breathitt	25,157	
Carter	21,965	
Floyd	4,596	
Jackson	4,602	
Johnson		101,523
Lawrence	27,660	
Lee	19,451	
Letcher		189,957
Morgan	18,749	
Perry	621,466	
Pike	185,312	
	963,664	291,480
Less	291,480	
Net gain	672,184	
Aggregate gains		3,653,093
Aggregate losses		1,135,887
Net gain		2,517,209

First Published October, 1919.

XII.

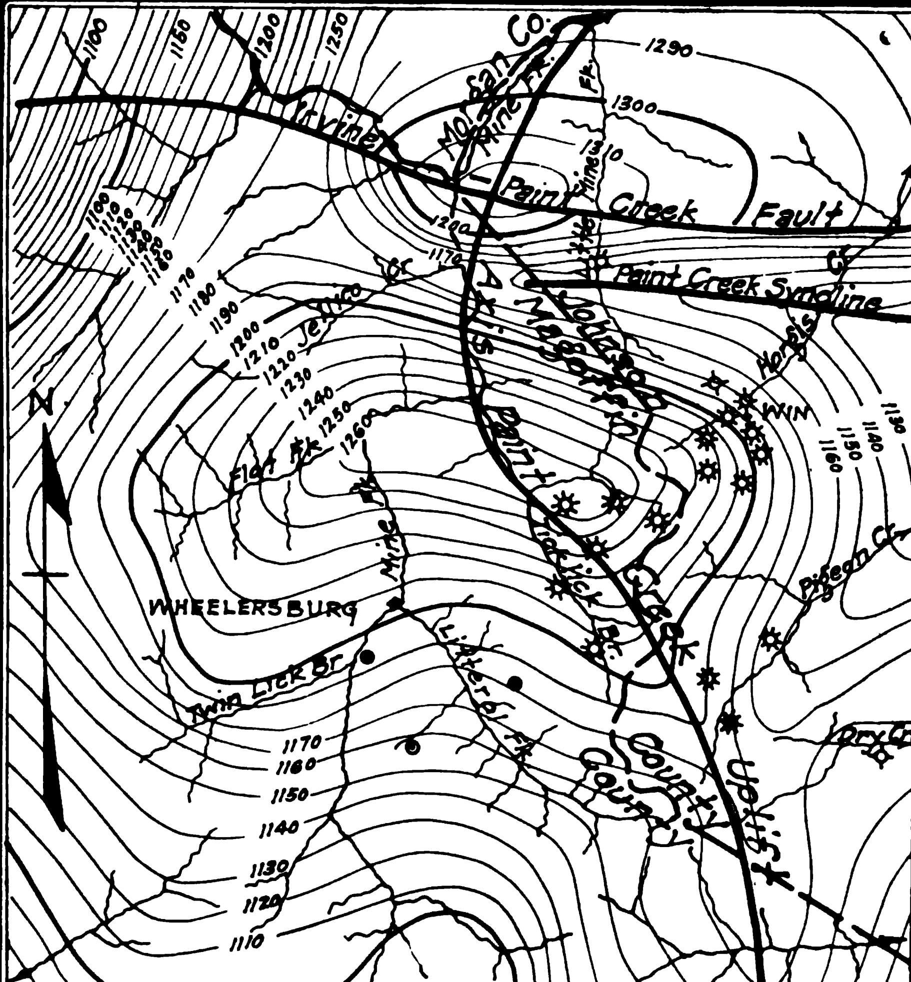
THE WIER SAND—A NEWLY RECOGNIZED OIL HORIZON IN EASTERN KENTUCKY.

INTRODUCTION

Within the last two years a considerable amount of oil and gas prospecting has gone forward in Johnson and Magoffin counties, on the headwaters of Mine Fork, Little Mine Fork and Pigeon Creek, of Paint Creek, and in Floyd County, near the mouth of Middle Creek. This development work has all been done under the geological advice and direction of two men, Mr. Iley B. Browning and the writer, who have made a detailed study of this section. Mr. Browning has confined his interest principally to the Paint Creek section, while the writer has devoted his attention to the area near Middle Creek. As a result of these investigations both oil and gas have been secured in commercial quantities in each of these localities, from a true silicious sand in the lower part of the Waverly. This sand has been definitely correlated with the Wier Sand of West Virginia, which is largely productive in the Hackbury and Blue Creek fields of Kanawha County.

In both the Paint Creek and Middle Creek localities this sand, which has been called the Wier, occurs on structure of the doming or anticlinal type, as mapped on surface coals, and substantiated by drilling. The development of commercially important oil and gas on both of these structures—the Paint Creek Dome and the Prestonsburg Anticline—operates as a splendid verification of the anticlinal theory of oil and gas accumulation, as it is now understood. The relative value of structure—the thickness and other lithological characteristics of the Wier Sand being the same—is also well demonstrated, since the larger oil and gas production of the Paint Creek Dome is directly in proportion to its superiority over the Prestonsburg Anticline in point of size and symmetry.

†Morse, W. C., and Foerste, A. F., The Waverlain Formations of East Central Kentucky. Ky. Geol. Surv. Series III, Bull. 16, 1912.



SKETCH MAP
SHOWING STRUCTURE AND WIER SAND PRODUCTION
ON
THE PAINT CREEK DOME
IN
JOHNSON AND MAGOFFIN CO'S., KY.

Prepared under direction of W. R. Jillson, State Geol. of Ky.
Field Geology by I. B. Browning.
Key Bed Fire Clay Coal.
Development Correct to October 1, 1919.

Scale: 0 — 1 — 2 Miles

The Paint Creek Dome shows a closed structural reversal of 80 feet to the north, an essentially closed reversal of 360 feet to the west, and 250 feet to the south. The structural fall to the southeast has not been determined, but is greater than that of any other direction, since this is the direction of the normal dip. The Wier Sand on the Paint Creek Dome is now producing 20,000,000 cubic feet of gas from thirteen wells, and one hundred barrels of oil from two wells, with one well producing both oil and gas not included.

The structure at Prestonsburg has been pierced by five wells, all of which produced oil, and two or three of which produced gas. The total oil production is somewhat less than one hundred barrels and the total gas production is less than 1,000,000 cubic feet. Though this amount of drilling on both structures has been completed, it is certain that neither the best locations, nor the full capacities of these structures have as yet been drilled. Besides the two structures above noted, the Wier Sand is also productive of oil and gas on the Laurel Creek Dome in northwestern Johnson County and Lawrence County. Various other points in Lawrence County are also productive of oil from the Wier, and new production has just been brought in from the same sand on the Ivyton Dome on the Arnett farm in Magoffin county.

Subsurface Stratigraphy

The Wier Sand has been referred to the lower part of the Waverly. As a matter of fact it is well toward the bottom of this important oil and gas subdivision of the Mississippian System, occurring from 235 feet (Boyd Conley No. 1, Magoffin County) to 457 feet (Middle Creek Coal Company No. 1, Floyd County) below the top of the St. Genevieve-St. Louis Limestone (Big Lime). It is undoubtedly a direct correlative and identical with the Cuyahoga Sandstone. The outcrop of this sandstone formation has already been described† as, "predominately even-bedded, argillaceous sandstones, alternating with shales." It is undoubtedly less shaly and more sandy under cover and in the productive localities.

STRATIGRAPHIC POSITION OF THE WIER OIL AND GAS SAND IN THE MISSISSIPPIAN SYSTEM OF EASTERN KENTUCKY.

Series	Group	Sand
Mauch Chunk	Mauch Chunk	Maxon
St. Genevieve-St. Louis	Big Lime	Big Lime Sand
Waverly	Big Injun	Keener* Big Injun* Squaw*
	Cuyahoga	WIER
	Sunburry**	
	Berea	Berea Grit

*Only one of the three sands generally present.
**A black shale—non-productive.

The Wier Sand, as it is found by the bit, is generally a gray, mediumly fine grain, true silicious sandstone, varying in thickness in productive wells from 31 feet (Boyd Conley No. 1, Magoffin County, to 43 feet W. J. Conley No. 3, Johnson County). In Magoffin County the depth below the Big Lime in five wells on the Paint Creek Dome is as follows:

F. M. Blanton No. 3....................344 feet
F. M. Blanton No. 2....................326 feet
J. C. Cantrill No. 1....................324 feet
Boyd Conley No. 1....................235 feet

In Magoffin County, on the Ivyton Dome, south of the Paint Creek Dome, the following depth is established:

Harris Howard No. 1	320 feet

In Johnson County two wells show the depth below the Big Lime to be as follows:

W. H. Conley No. 3	340 feet
Leroy Adams Oil Co. No. 3 (Barnett's Creek)	449 feet

In Floyd county these depths below the Big Lime are found, the Middle Creek Coal Company No. 1, at the mouth of Middle Creek, showing 457 feet, and the W. S. Harkins No. 1, on Trimble Branch, showing 455 feet. In the Hackberry and Blue Creek fields of Kanawha County, West Virginia, the Wier Sand is from 350 to 390 feet below the top of the Big Lime. The following thicknesses of sand have been determined:

Magoffin County—	
F. M. Blanton No. 3	38 feet
F. M. Blanton No. 2	42 feet
J. C. Cantrill No. 1	38 feet
Boyd Conley No. 1	31 feet
Harris Howard No. 1	40 feet
Johnson County—	
W. H. Conley No. 3	43 feet
Leroy Adams Oil Co. No. 3 (Barnett's Creek)	34 feet
Floyd County—	
Middle Creek Coal Co. No. 1	38 feet
W. S. Harkins No. 1	40 feet

The true position of the Wier Sand is immediately above the Black Sunbury Shale, which latter formation separates it from the Berea Grit, which is the bottommost formation in the Mississippian System. The actual subsurface stratigraphic position of the Wier Sand in the developed sections of Magoffin, Johnson and Floyd counties is given in the logs of seven productive wells, which are herewith presented.

MAGOFFIN COUNTY

LOG No. 1.

F. M. BLANTON—No. 2.

Bed Rock Oil Co. Well, on F. M. Blanton Farm on Big Branch of Ticklick Branch of Mine Fork of Little Paint Creek, in Magoffin County.

Elevation Surface 960 A. T.

PENNSYLVANIAN SYSTEM.

Strata	Thickness	Depth	
Drift	0	6	
Slate	21	27	
Coal	1	28	
Slate	11	39	
Gray sand	51	90	
White sand	80	170	
White sand	65	235	Fresh water and strong show of oil.
Gray shale and slate	107	342	
White sand	53	395	
Shale and gray sand	10	405	
White sand	5	410	
MISSISSIPPIAN SYSTEM:			
Gray sand and lime	10	420	
Green shale	10	430	
Sand and blue shale	19	449	
White lime—Big Lime	61	510	Big Lime—460 ft. of casing.
Gray and blue shale	104	614	
Limy sand	161	775	
Gray sand	41	817	Weir. Gas from top to bottom. 987,000 cu. ft. of gas.
Black shale—Sunbury	15	832	

Time of drilling 8 days. Drilled by E. F. Henry.

LOG No. 2.

Bed Rock Oil Co.'s J. C. Cantrill No. 1, on Ticklick Branch of Mine Fork, in Magoffin County.

Elevation Surface 955 A. T

PENNSYLVANIAN SYSTEM

Strata	Thickness	Depth
Drift		15
Sandstone	85	100
Sand and shales	100	200
Sandstone	110	310
Sandstone	2	312
Blue Clay	13	325
White sandstone	48	373

MISSISSIPPIAN SYSTEM.

Blue clay	2	375	
Shelly lime and shales	42	417	
Blue clay	9	426	
White lime	78	504	Big Lime casing set at 440.
Gray shales	208	712	
Sandy lime	28	740	About 50,000 cu. ft. gas.
Black shale	10	750	
Gray sand	38	788	Weir sand gas from top to bottom, 850,000 cu. ft.
Sandy shales	31	819	

Rock Pressure 285.

LOG. No. 3.

Bed Rock Oil Co.'s Boyd Conley No. 1, on Ticklick Branch of Mine Fork in Magoffin County.

Elevation Surface 905 ft.

PENNSYLVANIAN SYSTEM.

Strata	Thickness	Depth	
Drift and sand		50	
Sandstone	140	190	
Coarse white sand	80	270	Fresh water at 200.
White sand	70	340	

MISSISSIPPIAN SYSTEM.

Blue clay with sandy breaks	25	365	
White lime	20	485	Big Lime cased at 400.
Brown shales	155	640	
Slate	10	650	
Sandy lime	15	665	Some gas.
Green shale	35	700	
Gray sand	31	731	175,000 cu. ft, gas.
Black shale	12	743	
Gray sand	26	769	555,000 cu .ft. gas.

Rock Pressure 285.

JOHNSON COUNTY

LOG No. 4.

RED ROCK OIL CO., W. H. CONLEY No. 3.

On the Head of Pigeon Creek of Little Paint Creek.
Elevation surface 935.

PENNSYLVANIAN SYSTEM.

Strata	Thickness	Depth		
Drift	0	to 12		
Shale—show black oil	58	70		
Sand—fresh water at 180	245	315		
Sandy shale	35	440		

MISSISSIPPIAN SYSTEM.

Strata	Thickness	Depth		
Gray shale	10	450		
Lime	8	458		
Shale, gray	5	463		
White lime	6	469		
Gray shale	10	479		
Lime	3	482		
Gray shale	3	485	Big lime. Casing set at	
White lime	90	575	497.5.	
Sandy lime	155	730		
Gray shale	40	770		
Sand	5	775		
Sand	5	780	212,000 cu. ft. gas.	
Hard fine sand	5	785		
Black shale	40	825		
Gray sand	7	832	555,680 cu. ft. gas.	Wier
Gray sand	8	840	681,120 cu. ft. gas.	
Gray sand	8	848	823,970 cu. ft. gas.	
Gray sand	20	868	979,000 cu. ft. gas.	
Blue shales	22	890		

Rock Pressure 285 pounds.

LOG No. 5.

BARNETTS CREEK.

Lessee, Leroy Adams Oil Co., Casing Head Elevation 702 ft.
Production 5 Barrels Light Green Oil.

Total Depth 1035 Feet.

Strata	Thickness.	Depth.
PENNSYLVANIAN SYSTEM.		
Sandstone, Pottsville	460	460

MISSISSIPPIAN SYSTEM.		
Grey shale	10	470
"Mauch Chunk" "Big Lime," gas 490, St. Louis	69	539
Pale green to grey shaley sandstone, Waverly	369	908
"Sunberry" shale	11	919
"Wier" sand (oil 919-053)	34	953
Hard sandy shale—Berea	77	1030
DEVONIAN SYSTEM.		
Black shale	5	1035

FLOYD COUNTY

LOG No. 6.

MOUTH OF MIDDLE CREEK.

Strata	Thickness	Depth
Soil Conductor		16
PENNSYLVANIAN SYSTEM.		
Shale	94	110
Coal	1	111
"Sandy" shale	139	250
Coal	6	256
Sand	86	342
Shale	80	422
"Beaver" sand	128	550
Black slate	6	556
"Horton" sand, salt water at 560 ft.	80	636
Sandy shale	191	827
MISSISSIPPIAN SYSTEM.		
"Maxon" sand	80	907
"Little" lime	24	931
"Pencil Cave"	2	933
"Big Lime," gas 6 5-8 casing 956ft.	113	1046
"Big Injun," small amount gas, top	159	1205
Lime shells	185	1390
"Weir" sand, gas and green oil from 1394	38	1428

Oil 30.55 Baume. Oil stood 200 feet high in well day after drilling into "Weir Sand." Log from A. Fleming, Manager, T. M. King, Driller.

LOG No. 7.

W. S. HARKINS FARM.

Trimble Branch.

Strata	Thickness	Depth
Alluvial Quicksand	40	40
PENNSYLVANIAN SYSTEM.		
Conglomerate shale, sand and lime	408	448
Top salt sand (gas 450)	5	453
Shale	35	498
Sand (water 670)	197	685
Lime	35	720
Sand, white, settling	30	750
Slate	50	800
Sand (oil and gas 800 to 812)	40	840
Shale, blue	79	919
MISSISSIPPIAN SYSTEM.		
"Maxon" sand	65	984
"Little Lime"	20	1004
"Pencil Cave"	3	1007
"Big Lime"	160	1167
Shells, sand and shale	257	1424
Brown shale	40	1464
"Berea" sand (first) oil 1467-1480	40	1464
Shale, black	3	1507
"Berea" sand	40	1547
DEVONIAN SYSTEM.		
Shale, black	148	1695
Shale, brown	20	1715
Sand, gray	5	1720
Shale, black		1750
Bottom of hole		1750

Casing put in 12½, 40 feet.
Casing put in 8¼, 115 feet.
Casing put in 6⅝, 1017 feet.
Shot well from 1467 to 1482 feet with 60 qts. nitro-glycerine.
Shot cleaned well. Well filled up about 90 ft. within forty minutes after shot.
Contractor—King Drilling Co., Huntington, W. Va.

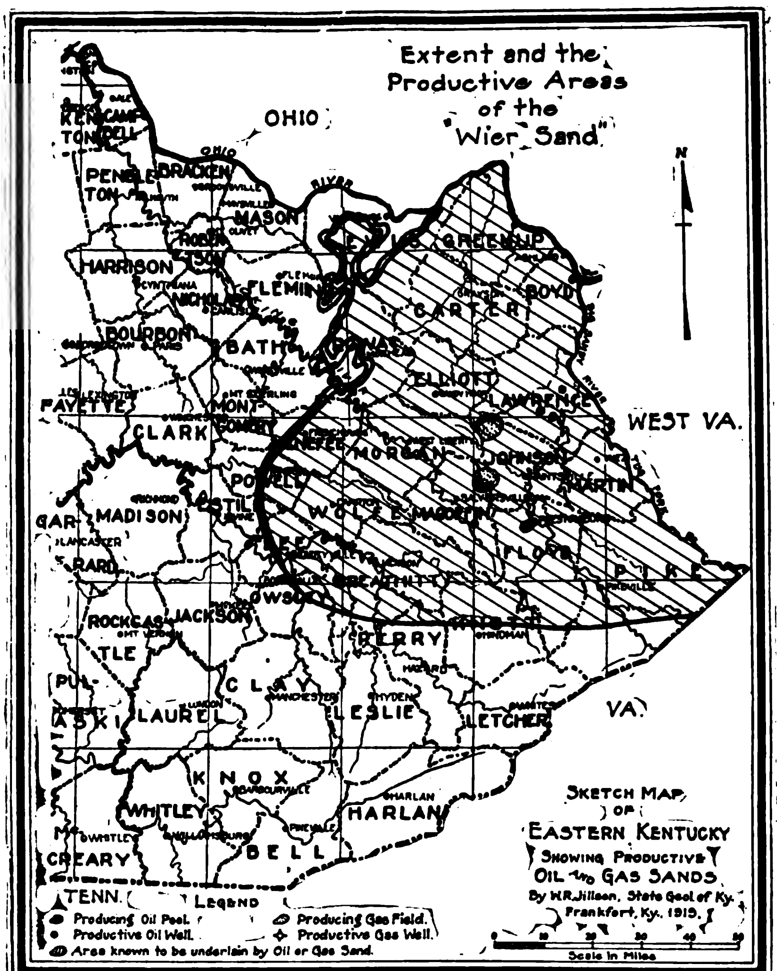
SUBSURFACE EXTENT OF THE WIER SAND.

With the determination of the Wier Sand as a newly productive horizon for both oil and gas in Eastern Kentucky, considerable attention has been paid to a study of its subsurface extent for the purpose of further prospecting. An examination

of the well logs of the eastern, especially the central-eastern portion of Kentucky, has revealed the fact that the Wier Sand as it is now known is not a widely extensive subsurface strata. It can be definitely recognized in the records of the drilled wells in Boyd, Lawrence, Johnson, Magoffin, Floyd and Martin counties, and is also present in the northern part of Pike, and the eastern portions of Greenup, Carter, Elliott, Morgan and Breathitt.

A comparison of the thicknesses of this sand shows it to reach its maximum known thickness of about 64 feet in Lawrence, Boyd and Martin counties. It thins rapidly to the southwest and northwest to productive thicknesses of about 30 to 40 feet, and from this thins down to such small and unproductive thicknesses as to be generally insignificant and unrecognizable by the driller. In Boyd County in the Big Sandy Oil and Gas Company well near Catlettsburg, on Catlett's Creek, the top of the Wier Sand is 1329 feet and the bottom is 1380 feet, giving a thickness of 51 feet. Oil shows were found in this well. In Elliott County, on the J. F. Dial's farm, near Isonville, the top of the Wier is 715 feet and the bottom 750 feet, giving a thickness of 35 feet. This well produced gas. On the Jess Peter's farm in Elliott County the top of the Wier is 783 feet and the bottom 836 feet, giving a thickness of 53 feet, a small part of which may not have been the Wier. Oil shows were encountered in this well. In Lawrence county the F. R. Bussey well, near Buseyville, shows the top of the Wier at 653 feet and the bottom at 717 feet, giving a thickness of 64 feet. The Jason Boggs, on Cane's Creek, shows the top of the Wier at 888 feet and the bottom at 952 feet, showing a thickness of 42 feet. The O'Brien Well, four and one-half miles south of Louisa, shows the top of the Wier at 1760 feet and the bottom at 1800 feet, giving a thickness of 40 feet.

A sketch map showing the known subsurface extent of the Wier Sand has been prepared and is included within this paper. The productive localities of the Wier have also been indicated by proper legending. The heavy dark line used to denote the geological limits of this sand must not be regarded as the actual line of pinching out of the Wier in Kentucky. It is, however, that line along which the sand becomes too thin to be



recognized by the driller. It is undoubtedly certain that as a thin stratigraphic leaf it extends considerably beyond this line before it actually pinches out entirely.

Summary

In summation, the Wier Sand has been definitely recognized and correlated as a new productive horizon of the Waverly in Eastern Kentucky. It is an extension of the Wier Sand of West Virginia, which is largely productive of both oil and gas in Kanawha County. Stratigraphically, the Wier Sand correlates with the Cuyahoga but may be considered for drilling purposes a downward subdivision of the Big Injun Series and therefore, in Kentucky, as in West Virginia, a unit with the Squaw Sand of the Big Injun Series, though separated by a definite shale. The subsurface extent of the Weir in Kentucky is not large, being confined principally to the Big Sandy and the upper waters of the Licking River drainage systems. The Wier Sand gives shows of oil in many scattered localities within this area. but is not known at present to be commercially productive outside of Magoffin, Johnson, Lawrence, Martin, Floyd and Pike counties. A single analysis of Wier Sand oil from the Middle Creek Coal Company No. 1 well, at Prestonsburg, is appended herewith for reference purposes. Partial volitalization of this sample prior to collection resulted in the small amount of the distillate below 150°.

Crude Petroleum Analysis

Laboratory No. G—3857. Petroleum labeled "Crude oil produced by the Great Central Company, Prestonsburg, from the Middle Creek Coal Co. No. 1 well at the mouth of Middle Creek, Floyd County, Ky. Collected by W. R. Jillson. October 29, 1918. From the 'Wier Sand,' 1425 feet." Sample had been exposed to air. Sample, a thick, green oil.

Specific gravity at 60° F., 0.877, equivalent to 29.6° Baume.

Distilled below 150° C. (302° F.)	none
Distilled between 150° and 300° C. (302-572° F.)	32.8%
Thick, oily residue	66.7%
Total	99.5%

Began to distill at 166° C. (320° F.)

ALFRED M. PETER, Chief Chemist.

(Analysis by A. M. Peter, Sept. 4, 1919.)

First Published October, 1919.

XIII.

THE PAY OIL SANDS OF EASTERN KENTUCKY.

Introductory

Not a little has been written concerning the commercially important oil sands of Eastern Kentucky. The literature concerning the productive horizons of this important section of the state is, however, chiefly of that kind which is devoted to the exposition of particular areas and separate oil and gas pools. With a single exception*, no publication has ever attempted to present a summary study of all of these sands under one title. This, however, is the purpose of this paper. Sectional sketch maps are included herewith showing the areas in the eastern portion of this state, where the various sands outcrop, and the areas beneath which they may be found by the drill. The geologic data herewith presented is based on personal field work done by the writer during the years 1917-1918-1919, during which time practically every important portion of Eastern Kentucky has been covered at least once or twice and many sections more often. Added to this the writer presents such facts as are seemingly well established by a study of about 500 logs of various wells drilled for oil and gas in the eastern part of this state. The information herewith given is intended to be summary rather than fully detailed, the article being written especially for the practical oil man, who wishes to gain a comprehensive understanding of the stratigraphic sequence of this portion of Kentucky. The sands herewith discussed are taken up in descending order, that is, from the Pennsylvanian System down through, to and including the Ordovician System. This is the order of actual super-position, that is, the order in which they would be penetrated by the drill.

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*Hoeing, J. B., The Oil and Gas Sands of Kentucky, Kentucky Geological Survey, Series III, Bulletin 1, 1919.

THE PENNSYLVANIAN SYSTEM

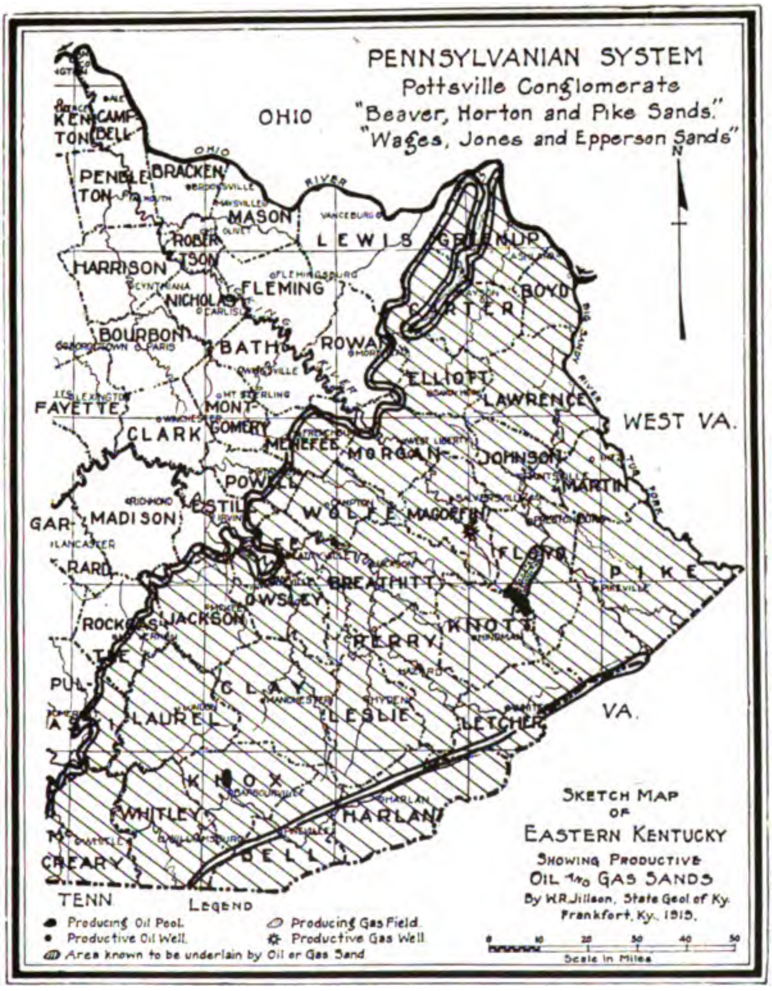
The Pottsville Conglomerate

The principal surficial rocks of Eastern Kentucky are those of the Pottsville or Lower Pennsylvanian. The Pottsville is divided into three sections, Upper, Middle and Lower. The lowermost Pottsville is found highest on the eastern flank of the Cincinnati Arch, along a line which is the double line, as shown on map, figure 1. Progressing to the southeast from this line of outcrop the Pottsville thickens immensely, the Middle and Upper Divisions coming in until when we reach the Pine Mountain Fault in Pike and Letcher counties, we find the Lee or Lower Pottsville alone to be about one thousand feet. Above this comprising the Middle and Upper Pottsville there is an interval of almost twice this thickness before the lowermost Alleghany sediments are reached in the top of some of the ridges.

The Pottsville is often spoken of as the Conglomerate, deriving its name from the conglomerate sandstones which appear towards its base. As a whole, however, the Pottsville is an alternation of sandstones, shales and coals and presents a very irregular sedimentary characteristic. The sandstones predominate throughout, but there are many sections where the shales are thick and frequently encountered. The thickening of the Pottsville toward the southeast is developed by the wedging out or thickening of separate sandstones and the growth of new shales and new coals as one progresses from the northwest to the southeast.

The Pottsville is an important producer of oil and gas, production coming from three sands in the Lower Pottsville, which is below drainage in the central part of this area. The productive sands in Floyd, Magoffin, Knott and Pike are the "Beaver," "Horton" and "Pike." In Knox and adjoining counties three sands are found, which are known as the "Wages," "Jones" and "Epperson." These are probably the correlatives of the productive horizons to the northeast. The logs of three wells, two in Floyd County and one in Knox County, are given herewith to illustrate the stratigraphic sequence of the sands.

FIG. 1.


PENNSYLVANIAN SYSTEM
Pottsville Conglomerate
"Beaver, Horton and Pike Sands."
"Wages, Jones and Epperson Sands"
OHIO
WEST VA.
VA.
TENN
SKETCH MAP OF EASTERN KENTUCKY SHOWING PRODUCTIVE OIL AND GAS SANDS
By W.R. Jillson, State Geol of Ky. Frankfort, Ky., 1919.
LEGEND
Producing Oil Pool.
Productive Oil Well.
Producing Gas Field.
Productive Gas Well
Area known to be underlain by Oil or Gas Sand
Scale in Miles

FLOYD COUNTY

LOG No. 1.

WELL RECORDS SHOWING POTTSVILLE SANDS, THE "BEAVER," "HORTON," AND "PIKE."

GEORGE ALLEN FARM.

Right Beaver Creek.

Strata	Thickness	Depth	
Drift	30	30	
PENNSYLVANIAN SYSTEM.			
Slate	12	42	
Coal	4	46	
Slate	18	64	
Gray sand	16	80	
Slate	23	103	
Gray sand	25	128	
Dark slate	25	153	
Light sand	22	175	
Dark slate	6	181	
Coal	3	184	
Dark slate	73	257	Pottsville
Light sand	36	293	
Slate	203	496	
Sand (Beaver)	246	742	
Light slate	6	748	
White sand (Horton)	165	913	
Coal	1	914	
Dark slate	5	919	
Gray sand	8	927	
Dark slate	58	985	
Sand (Pike)—Gas and oil	29	1014	
Dark slate	4	1018	
Gray sand (Base Pottsville)	13	1031	
MISSISSIPPIAN SYSTEM.			
Dark slate	4	1035	
Gray sand	10	1045	
Slate and red rock	8	1053	Mauch Chunk
Sand (Maxon) Gas and salt water	31	1084	
Black slate	45	1129	
Sand	50	1179	

LOG N. 2.

JAMES HICKS FARM.

Head of Brush Creek of Right Beaver Creek.

PENNSYLVANIAN SYSTEM.

Strata		Thickness	Depth	
Soil		18	18	
Slate		21	39	
Gray sand		2	41	
Slate		15	56	
Gray sand		18	74	
Slate		26	100	Pottsville
Gray sand		10	110	
Slate		25	135	
Gray sand		112	247	
Slate		153	400	
Gray sand		12	412	
Slate		38	450	
Gray sand		25	475	
Sandy slate		73	548	
Sand—gas	(Beaver)	82	630	
Dark slate	(Beaver)	5	635	
White sand—gas	(Beaver)	54	689	
Dark slate		3	692	
White sand—salt water	(Horton)	127	819	
Coal and slate	(Horton)	2	821	
White sand	(Horton)	83	904	
Coal		1	905	
Gray sand		7	912	
Dark slate		38	950	
White sand (Pike)—Gas		69	1019	

MISSISSIPPIAN SYSTEM.

	Thickness	Depth	
Dark slate	30	1039	Mauch Chunk
Sand (Maxon)—Oil and salt water	115	1164	

LOG N. 3.

JOHN MARTIN FARM.

Right Beaver Creek.

Strata	Thickness	Depth	
Soil	25	25	
PENNSYLVANIAN SYSTEM.			
Slate	25	50	
Coal	3	53	
Slate	17	70	
Sand	51	121	
Slate	34	155	
Sand	55	210	
Slate	2	212	
Sand	29	241	
Slate	194	435	
Sand (Beaver)—Gas	219	654	
Coal	2	656	Pottsville
Slate	29	685	
Sand (Horton)	105	790	
Slate	3	793	
Sand	31	824	
Slate	3	827	
Sand	35	862	
Slate	35	897	
Sand (Pike)—Oil	56	953	
Slate	34	987	
Sand	10	997	
Slate	5	1002	
Sand (Base Pottsville)	18	1020	
MISSISSIPPIAN SYSTEM.			
Slate	29	1049	
Sand (Maxon)	67	1116	Mauch Chunk

From a structural standpoint the productive areas of the Pottsville, in Eastern Kentucky, are geo-synclinal, and the oil in the Knott-Floyd section is found in a local basin syncline as mapped on surface coals. A consideration of these facts leads to the conclusion that oil will later be found in important quantities in the Pottsville, except along that synclinal belt, which runs from Whitley, through Knox, Clay, Perry, Breathitt, Magoffin, Floyd and Pike counties. The factors which seem to favor the finding of oil along this line are thickness of the cover and thickness of the sand. To the northwest the productive

sands become thin, some of them rapidly, and the cover thins rapidly in the same direction. Towards the southeast these sands become quite deep, the base of the Pottsville being in some portions probably at least two thousand feet below the surface. On the other hand at some points, at least along the Pine Mountain Fault, radiating breaks or faults, and sharp crested anticlines have resulted in destroying the necessary cover and protection. Unbroken structure paralleling the Pine Mountain Fault should, however, prove productive upon systematic drilling.

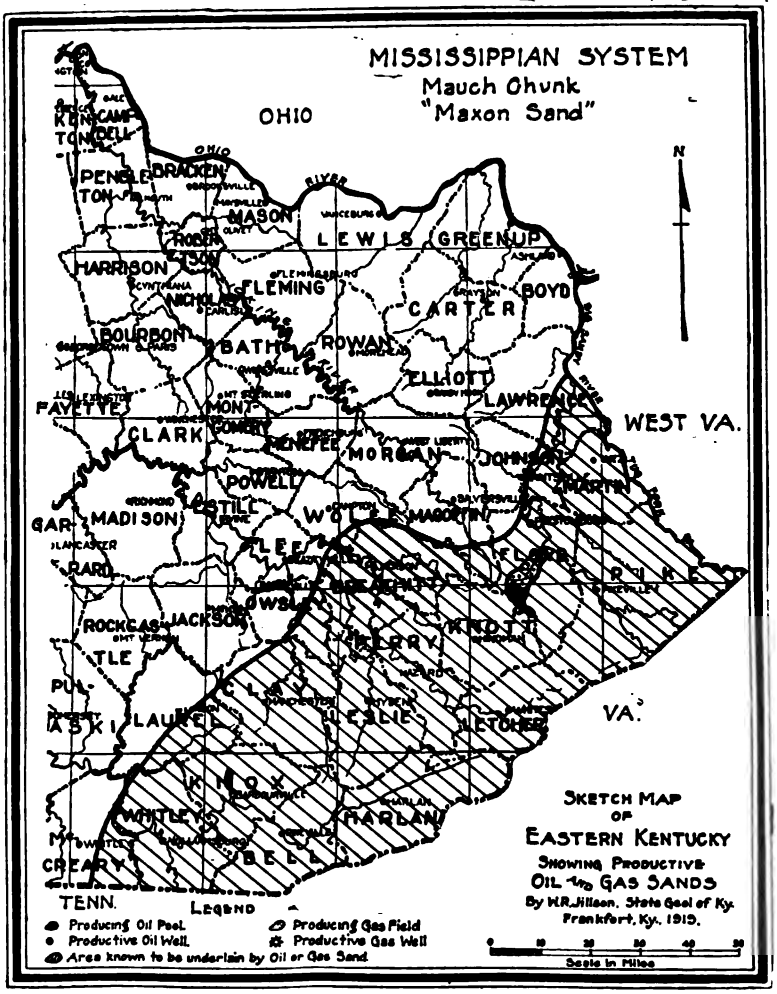
THE MISSISSIPPIAN SYSTEM

THE MAUCH CHUNK

Unexposed at any point in Eastern Kentucky, except in a very narrow strip along the Pine Mountain Fault, the Mauch Chunk or uppermost division of the Mississippian System remained unannounced* as an important oil and gas producer of this section until the present year. It is now known that the Maxton Sand (corrupted by drillers to Maxon) is the principal producer of both oil and gas in Floyd County and the adjoining sections of Knott, in the Beaver Creek field. It is also an important producer in the Little Richland field, in Knott County. The geographic delimitations of the Mauch Chunk herewith presented have been obtained by a study of well logs, and it is believed that the northwestern boundary, as indicated on sketch map, Figure No. 2, is approximately the northwestern boundary line of the typical Mauch Chunk. From Lawrence to Breathitt County this line represents the discernible limit of the Mauch Chunk. From Breathitt County south to McCreary this line is one of transition from the typical Mauch Chunk (red and green and largely clastic) over into the more typical Chester Limestones and sands of light color.

*Jillson, W. R., The Status of the Mauch Chunk in Eastern Kentucky as a Producer of Petroleum and Natural Gas. Department of Geology and Forestry. Series V. Mineral and Forest Resources, Vol. 1, No. 2, 1919.

FIG. 2.



The Mauch Chunk is essentially an alternation of clastic sediments, which become more calcareous and show several bastard limestones toward the bottom of the group. The upper part is alternately shaly and sandy, the shales being either reddish, pinkish or green, and the sands tan to white. This coloration makes this horizon easily identified, either from drill samples or outcrops. The Mauch Chunk occupies essentially the

south-eastern limb of the Eastern Kentucky Geo-syncline, and its structure is theoretically similar to the overlying coals of the Pottsville. Actually, however, the considerable and widespread unconformity between the basal Pottsville and the Mauch Chunk introduces an error, which has been repeatedly proven by drilling records. The surface geology therefore may be used as an index to the structure of the Mauch Chunk, but may not be relied upon as an absolute reflector of the subsurface structure. An instance of the departure from the rule is probably existent in the structural geology of the Beaver Creek field, in Floyd and Knott counties. The surface structure of this field is a basin syncline, but there is sufficient evidence procurable from a study of the well logs of this vicinity to suggest that irregularities of structure, not apparent at the surface, do exist at and above the principal producing horizon, which is the Maxton Sand of the Mauch Chunk. The logs of two wells in eastern Kentucky are given herewith to illustrate the stratigraphic sequence of the Mauch Chunk group.

LOG No. 4.

WELL RECORDS SHOWING THE MAUCH CHUNK AND THE MAXTON ("MAXON") SAND.

AKER BRANCH LEFT BEAVER CREEK

Strata	Thickness	Depth	
Drift 10 inch casing		44	
PENNSYLVANIAN SYSTEM.			
Slate	36	80	
Sandstone	20	100	
Slate	120	220	
Sandstone	35	255	
Slate	100	355	
Sandstone	20	375	
Slate	125	500	Pottsville
Sandstone (Beaver)	190	690	
Sandstone	59	808	
Slate	10	818	
Sandstone	5	823	
Slate	12	835	
Sandstone	10	845	

MISSISSIPPIAN SYSTEM.

Red rock	18	863	
Slate	38	901	
Sandstone (Maxon)	51	952	
Limestone	6	958	
Slate	8	966	
Red rock	99	1065	
Slate, sandstone	15	1088	
Slate	30	1110	Mauch Chunk
Limestone	10	1120	
Slate	10	1130	
Dark lime	77	1207	
Sandstone (Gas)	30	1237	
Limestone, shale	33	1270	
White lime (Big Lime)	140	1410	St. Genevieve-St. Louis
Sand (Big Lime)	5	1415	
White lime (Big Lime)	19	1434	
Red Shale (Big Injun)	50	1484	
Slate (Big Injun)	47	1531	
Shale and sand	234	1765	
Brown shale	19	1784	
Sandstone "Wier"	45	1829	
Brown slate	150	1979	Waverly
Berea sand	21	2000	
Slate	2	2002	Total Depth

Note—Beaver sand showed gas at 537, oil and gas at 572, and unlimited saltwater at 660. Big Lime showed gas at 1396. Wier sand showed "Amber" oil at 1784. Berea showed gas 1979-1994.

KNOX COUNTY

LOG No. 5. C. P. KENNEDY FARM.
East of Barbourville.

Strata	Thickness	Depth
Loam	38	38
PENNSYLVANIAN SYSTEM.		
Black sand	22	60
Coal	3	63
Black slate	7	70
Gray sand	15	85
Black slate	70	155
Coal	4	159
Black slate	6	165
Gray sand	21	186
Black slate	19	205
Gray sand—oil show at 210	35	240

Black slate	68	308	Pottsville
Gray sand	27	335	
Black slate	15	350	
White sand—oil show at 385	95	445	
Black slate	18	463	
Gray sand	107	570	
Black slate and shells	25	595	
White sand	75	670	
Black shale	10	680	
Black slate	40	720	
White sand—salt water at 743	43	763	
Black slate	37	800	
Brown sand	60	860	
Black shale	10	870	
White sand	105	975	
Black slate	47	1022	
White sand	15	1037	
Black slate	23	1060	
White sand (base of Pottsville)	15	1075	
MISSISSIPPIAN SYSTEM.			
Blue lime	15	1090	Mauch Chunk
Red rock	18	1108	
White sand	5	1113	
Red rock	32	1145	
Black slate and shells	63	1208	
Red rock	20	1228	
Blue slate	32	1260	
Brown sand—oil show at 1270 Maxon	26	1286	
Blue slate	24	1310	
Blue lime	15	1325	
Blue slate	65	1390	
Brown lime—gas show at 1395	12	1402	
White slate	10	1412	
White lime—"Big lime"—gas show at 1470	143	1815	St. Gen.-St. Louis
Slate and shells	260	1815	Waverly
Blue "flint"	15	1830	
Gray sand	55	1885	
White slate and shells	20	1905	

DEVONIAN SYSTEM.

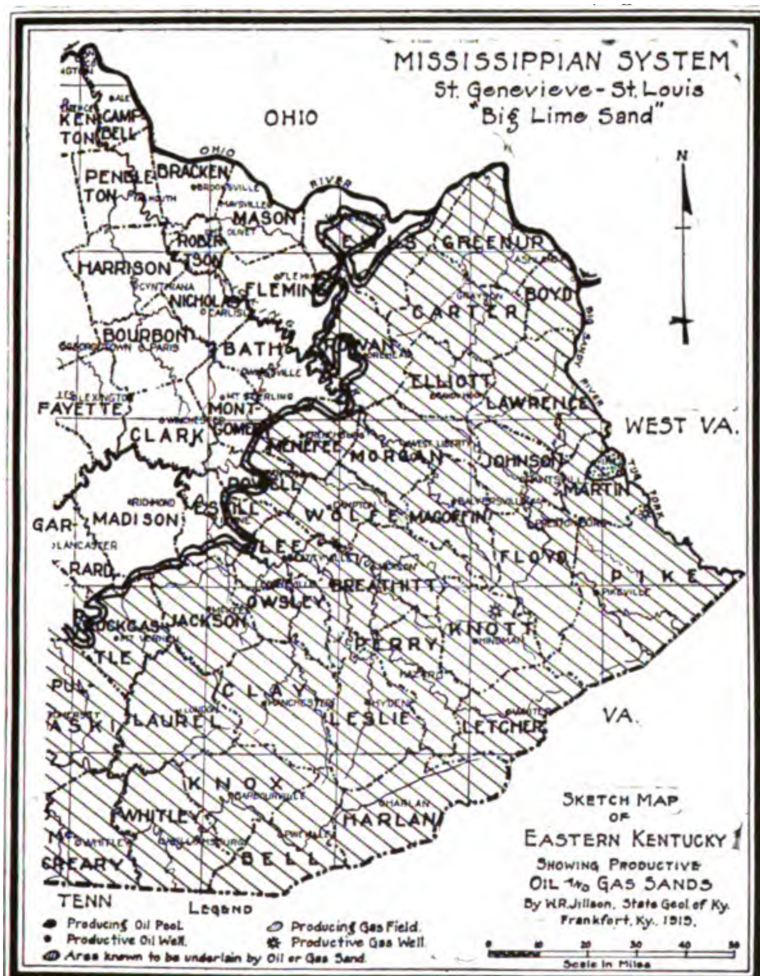
Black shale	145	2050	Chattanooga
White slate and shells	135	2185	
Pink slate	55	2240	
White slate	15	2255	
Red rock	25	2270	
Slate and shells	230	2500	

Note—The base of the Devonian System and the top of the Silurian cannot be marked as it is included in the 135 feet of white slate and shells just below 2050 feet.

THE ST. GENEVIEVE-ST. LOUIS LIMESTONES

The first and most easily recognized limestone horizon is that which is known as the Big Lime. This horizon has been separated by stratigraphers into two divisions, the St. Genevieve and the St. Louis Limestones. At most points in Eastern Kentucky these limestones are separated by a relatively thin layer of sandstone, which has become known as the Big Lime Sand. This sand parting between these prominent limestones is easily recognized in central and southeastern Eastern Kentucky, but is not so easily seen in northeastern Eastern Kentucky. The Big Lime itself varies in thickness from 35 feet on the outcrop in northeastern Kentucky, to 250 feet in southeastern Kentucky, and 395 feet in Whitley County, the extreme southwestern portion of Eastern Kentucky. The Big Lime Sand is chiefly important as a gas horizon, being largely productive on the Warfield Anticline, in Martin County, and showing strong gas on the Yellow Mountain Anticline, in Knott County. Its line of outcrop is the double line as shown on the sketch map, Figure 3. While the surface structure of the western edge of the Eastern Coal field probably reflects the subsurface structure of the Big Lime, due to the immense thickening of the Pottsville as one progresses to the southeast and the introduction in this same section of the irregular Mauch Chunk group, the Big Lime in the southeastern portion of Eastern Kentucky may not be regarded as conformable except to a very slight degree to the surface structure in this portion of the state. The counties in which the Big Lime would therefore be out of accordance with the surface structure to the largest degree would be Pike, Letcher, Harlan and Bell, and to a lesser degree, McCreary,

FIG. 3.



Whitley, Knox, Clay, Leslie, Perry, Knott, Magoffin, Johnson, Floyd and Martin. Five representative well logs have been introduced to show the sequence and position of the Big Lime in this section of the state.

ELLIOTT COUNTY

LOG No. 6

WELL RECORDS SHOWING ST. GENEVIEVE-ST. LOUIS LIMESTONE, THE "BIG LIME" SAND.

J. F. DIALS FARM.

Isonville.

Strata	Thickness	Depth	
Quicksand	25	25	
PENNSYLVANIAN SYSTEM.			
Slate	115	140	
Sand	30	170	Pottsville
Slate—Cased at 180	10	180	
Dark sand	20	200	
MISSISSIPPIAN SYSTEM.			
Slate	40	240	
White lime—"Big lime"—Gas at 338	150	390	St. Gen.-St. Louis
Dark sand (Probably Big Injun)	15	405	Waverly
Slate and shell—Cased at 560	225	630	Waverly
Lime	40	670	Waverly
Gray sand—Gas at 715	80	750	Waverly
Slate	20	770	Waverly
Sand	95	865	Waverly
Slate and shell	29	894	Waverly
DEVONIAN SYSTEM.			
Black shale	376	1270	Chattanooga
White slate	77	1347	
SILURIAN SYSTEM.			
Sandy lime	35	1382	
Gas at 1348			
Strong gas at 1366.			
Bottom of well at		1500	

CARTER COUNTY

LOG No. 7 WELL NEAR DENTON.

Strata	Thickness	Depth	
PENNSYLVANIAN SLSTEM.			
Soil	5	5	
Quicksand	65	70	
Sand hard	80	150	
Shale	50	200	Pottsville
White sand	50	250	
Shale	50	300	
Sand (base of Pottsville)	20	500	

MISSISSIPPIAN SYSTEM.			
"Big Lime"	90	590	St. Gen.-St. Louis
"Waverly"	390	980	
Black shale (Sunbury)	90	1070	Waverly
"Berea sand"*	100	1170	
DEVONIAN SYSTEM.			
Black shale	500	1670	Chattanooga
Blue shale	100	1770	
"Clinton"*	70	1840	

*Driller's distinction, obviously incorrect.

Base of Devonian indefinite.

JOHNSON COUNTY

LOG No. 8.

THOMAS OSBORN FARM.
Toms Creek.

Strata	Thickness	Depth	
PENNSYLVANIAN SYSTEM.			
Soil	39	39	
Dark slate	126	165	
Gray sand	210	375	Pottsville
Dark slate	95	470	
White sand (base of Pottsville)	85	555	
MISSISSIPPIAN SYSTEM.			
"Big Lime"	159	714	St. Gen.-St. Louis
Dark sand	136	850	
Dark slate	170	1020	
Black slate	15	1035	
Gray sand	90	1125	Waverly
White slate	20	1145	
Black slate (Sunbury?)	35	1180	
Dark sand (Berea?)	30	1210	
DEVONIAN SYSTEM.			
Black shale	400	1610	Chattanooga
White slate	105	1715	
Lime	97	1812	

Base of Devonian indefinite.

CLAY COUNTY

LOG. No. 9.

Nancy Potter, No. 1, on Blue Salt Run, a Branch of Goose Creek. 8 miles west of Manchester. La Salle Oil Co., Operators. Elevation about 950 feet.

Strata	Thickness	Depth	
PENNSYLVANIAN SYSTEM.			
Soil	9	9	
Shell	3	12	Pottsville
Gravel	6	18	
Sand	4	22	
Coal	5	27	
Dark shale	131	158	
Hard sand	106	264	
Brown shale	10	274	
Sand	146	420	
Dark shale	40	460	
Light shale	25	485	
MISSISSIPPIAN SYSTEM.			
Red rock	15	500	Mauch Chunk
Slate	50	550	
Red rock	5	555	
Light shale	5	560	
Big lime	240	800	St. Gen.-St. Louis
Big Injun	55	855	Waverly
Red rock	7	862	
Dark shale	528	1190	
DEVONIAN SYSTEM.			
Black shale	135	1325	Chattanooga
Light shale	25	1350	
Black shale	10	1360	
Black lime	5	1365	
Brown shale	35	1400	
Gray lime, hard	15	1415	
SILURIAN SYSTEM.			
Blue slate	5	1420	Niagaran
White slate	85	1505	
Red rock	5	1510	
Blue slate	25	1535	
Dark sand	10	1545	
Green slate	115	1660	

ORDOVICIAN SYSTEM.

Brown lime	10	1670	
Green slate	25	1695	
Soft white lime	5	1700	
Green slate	10	1710	
Red rock	20	1730	
Green slate, very hard	12	1742	
Gray lime, hard	18	1760	
Slate and shells	20	1780	
Gray slate	50	1830	
Gray lime	20	1850	
Lime, shells, slate	25	1875	
Lime and flint with flakes of slate	15	1890	
Lime, flint	170	2060	
Gray lime	40	2100	
Lime and slate	60	2160	Trenton
Blue slate	30	2190	
Gray lime, dark	15	2205	

Note—The Big Lime shows gas at 700 feet. Gas was also secured at 1350 at the Onondaga horizon in the Devonian.

KNOTT COUNTY

LOG No. 10.

ROCK FORK JUST BELOW BRUSHY FORK. W. R. BOLEN No. 1. Lessee, Pennagrade Oil and Gas Co.

Completed July, 1916. Production 4,680,000 cu. ft. gas. Producing Sand "Big Lime."

Casing Head Elevation 950 Aneroid. Total Depth 1635 feet.

Strata	Thickness	Depth
Drift 20 feet 10 inch casing		20

PENNSYLVANIAN SYSTEM.			
White sand	5	25	
Coal	5	30	
Dark slate	120	150	
Dark sand 8 inch casing	30	180	
Slate	5	185	
Sand	30	215	
Coal	5	220	
Slate	20	240	
Sand	70	310	
Slate	15	325	
Sand	95	420	
Slate	15	435	Pottsville
Sand	45	480	
Slate	280	760	
Sand	148	908	
Break	2	910	
Sand (water at 950)	80	990	
Break	10	1000	
Sand (little oil at 1060 feet)	170	1170	
Slate	10	1180	
Sand	40	1220	
Shale	20	1230	
Sand	40	1270	
MISSISSIPPIAN SYSTEM.			
Slate	30	1300	
"Maxon" sand (oil at 1305)	123	1423	
Black slate	14	1437	
Sandstone, light sandy	13	1451	
Slate and shells	25	1476	Mauch Chunk
"Little" lime	15	1491	
"Pencil Cave" shale	9	1500	
"Big Lime" Gas in Big Lime at 1630	135	1635	

4,680,000 cu. ft. gas, open flow 540 pounds Rock Measure.
Well completed July, 1916. Not shot.
1440 6 5-8 inch casing.
1637 2 inch tubing.
Elevation 945 feet.
A. B. Brode and Son, Contractors. S. L. Anderson, Driller.
135 feet is not the full thickness of the "Big Lime" formation.

WHITLEY COUNTY

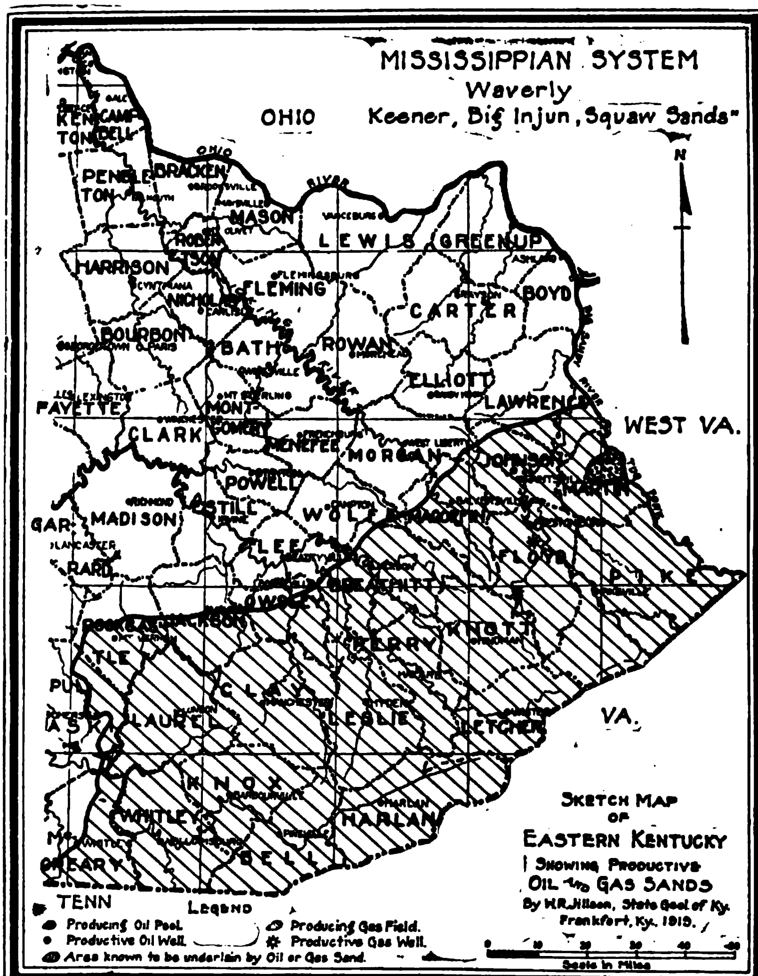
LOG No. 11.

J. P. SHARP FARM.
Rockhold Station.

Strata	Thickness	Depth	
PENNSYLVANIAN SYSTEM.			
Soil	14	14	Pottsville
Black shale	36	50	
White lime	5	55	
Coal	1½	56	
Blue slate	88½	145	
White sand	10	155	
Black slate	30	185	
White sand	20	205	
Black slate	110	315	
Gray sand	190	505	
Black slate	40	545	
White sand	165	710	
Black slate	30	740	
White sand—oil show	230	970	
Black slate	35	1005	
Sand	26	1031	
Coal	2	1033	
Black slate	4	1037	
White sand	5	1042	
Black shale	15	1057	
MISSISSIPPIAN SYSTEM.			
White lime	5	1062	
Black shale	4	1066	
White sand	25	1091	
White shale	60	1151	Chester
White lime	54	1205	
White shale	50	1255	
White lime	30	1285	
White shale	5	1290	
White lime (Big lime)	265	1555	St. Genevieve-St. Louis
Brown sand	35	1590	
Blue sand	27	1617	
Blue shale	188	1805	
DEVONIAN SYSTEM.			
Brown shale	120	1925	
White shale	15	1940	Chattanooga.
Brown shale	5	1945	

SILURIAN SYSTEM.		
White shale	60	2005
Red shale	5	2010
White shale	35	2045
Red shale	15	2060
White shale	5	2065
White lime	70	2135
ORDOVICIAN SYSTEM.		
Shale	70	2205
White lime	25	2230

FIG. 4.



THE WAVERLY GROUP

Directly underlying the St. Genevieve-St. Louis Limestone and in the lower part of the Mississippian System, as it is known in Kentucky, there is a series of several hundred feet of alternating limestones, shales and sandstones. This group is known as the Waverly in Kentucky. In West Virginia it is called the Pocono Group. The upper portion of the Waverly contains in descending order the Keener, Big Injun, and Squaw Sands, one or more of which are generally present, though it is very seldom if ever that the three are found in any one well. These three sands are intercalated between thick and rather easily identified red shales, known to the driller as red rock. Taken together these three sands are known as the Big Injun Group and are important productive horizons for both oil and gas in Eastern Kentucky. The principal production is secured in Martin, Pike, Johnson, Floyd, Breathitt, Clay and Knox counties. Figure 4 shows by sketch map the approximate northwestern limit of this group of petroliferous sands. This line is not a line of outcrop, but is one determined by a study of many well logs, two of which are presented herewith to show the sequence and depth of these sands.

FLOYD COUNTY

LOG No. 12.

WELL RECORDS SHOWING THE WAVERLY AND THE "BIG INJUN" SAND.

JOHN GRAY FARM.

Head of Bull Creek.

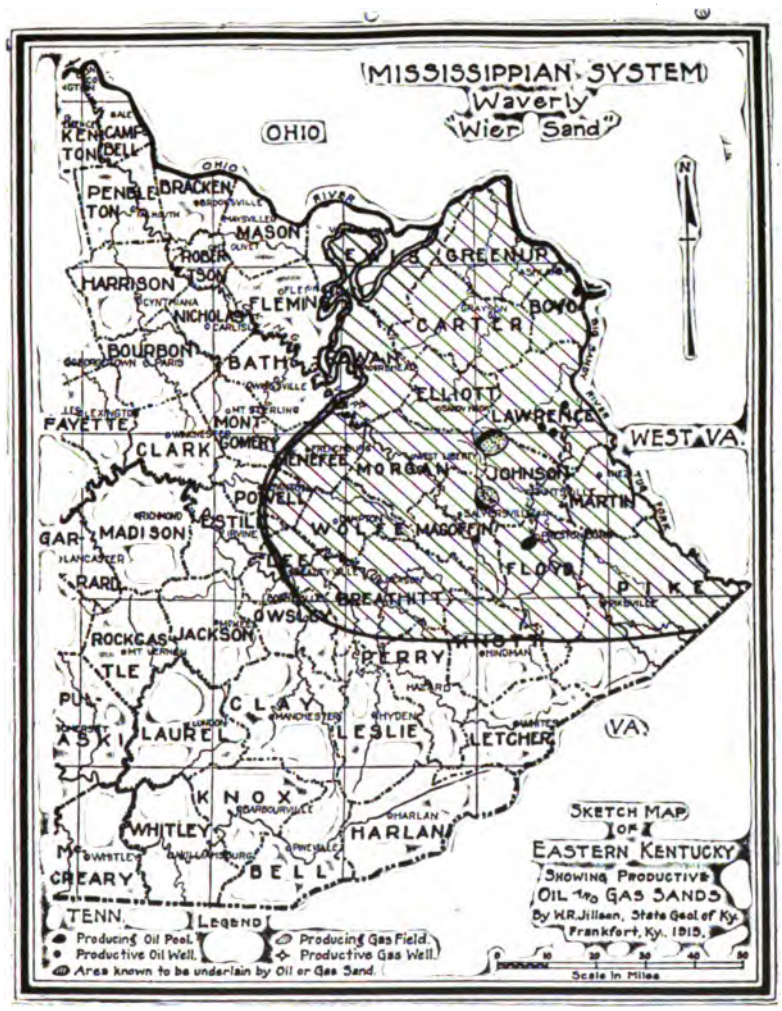
Strata	Thickness	Depth	
Gravel	14	14	
PENNSYLVANIAN SYSTEM.			
Sand and shale	26	40	
Coal	4	44	
Shale and shells	266	310	
Sand	90	400	
Shale and shells	100	500	
Sand (Beaver)—Gas at 610 water at 625	200	700	Pottsville
Shale	22	722	
Coal	2	724	
Sand—Water at 756	72	796	
Slate and shell	50	846	
Sand	74	920	

MISSISSIPPIAN SYSTEM.			
Red shale	30	950	
Gray shale	41	991	Mauch Chunk
Sand (Maxon)	93	1084	
"Little lime"	24	1108	
"Pencil Cave"	15	1123	
"Big lime"—Oil show at 1190	162	1285	St. Genevieve-St. Louis
Lime shells	268	1593	
Brown shale (Sunbury?)	20	1613	Waverly
1300	40	1325	
Brown shale (Sunburw?)	20	1613	
Lime—Oil show at 1628	80	1693	
DEVONIAN SYSTEM.			
Black shale and shells	135	1828	
Gray slate	15	1843	
Shells and shale	576	2419	
Flinty lime	19	2440	

The Big Injun Series, like the overlying Big Lime, is probably conformable only to the larger surface structures.

Underlying the Squaw Sand and separated from it by a definite shale is found a recognizable petroliferous sand of rather limited geographic distribution in Eastern Kentucky. This sand. from a practical standpoint the lowermost subdivision of the Squaw or Big Injun Group, has been identified and correlated with the Cuyahoga Sandstone. It is called the Wier Sand. It is essentially a southeastward extension of a sand productive in West Virginia and its extension in Kentucky as far as can now be determined is indicated by the sketch map, Figure 5. The Wier Sand is now known to be an important oil and gas horizon in Kentucky. Further development and prospecting will reveal much more concerning it within the next few years. Two logs are herewith presented to show its stratigraphic position and depth.

FIG. 5.


MISSISSIPPIAN SYSTEM
Waverly
"Wier Sand"
OHIO
WEST VA.
VA.
TENN.
SKETCH MAP
OF
EASTERN KENTUCKY
SHOWING PRODUCTIVE
OIL AND GAS SANDS
By W.R.Jillson, State Geol. of Ky.
Frankfort, Ky., 1915.
LEGEND
Producing Oil Pool.
Productive Oil Well.
Producing Gas Field.
Productive Gas Well.
Area known to be underlain by Oil or Gas Sand.
0 10 20 30 40 50
Scale in Miles
KENTON
CAMPBELL
PENDLETON
BRACKEN
MASON
ROBERTSON
HARRISON
NICHOLAS
FLEMING
LEWIS
GREENUP
BOYD
CARTER
BOURBON
BATH
ROWAN
ELLIOTT
LAWRENCE
FAYETTE
CLARK
MONTGOMERY
MENIFEE
MORGAN
JOHNSON
MARTIN
POWELL
MADISON
ESTILL
WOLFE
MAGOFFIN
FLOYD
LEE
BREATHITT
PIKE
OWSLEY
JACKSON
ROCKCASTLE
KNOTT
PERRY
CLAY
LAUREL
LESLIE
LETCHER
KNOX
WHITLEY
HARLAN
BELL
McCREARY

MAGOFFIN COUNTY

WELL RECORDS SHOWING THE WAVERLY AND THE "WIER" SAND.

LOG No. 13.

F. M. BLANTON—No. 3.

Bed Rock Oil Co., on Big Branch of Ticklick Branch of Mine Fork in Magoffin County.

Elevation Surface 1025 ft.

Strata	Thickness	Depth	
PENNSYLVANIAN SYSTEM.			
Drift		24	
Slate	76	100	Pottsville
Brown sand	40	140	
White sand	60	200	
White sand	100	300	
Shale and slate	124	424	
Brown sand	11	435	
Brown sand	25	460	
MISSISSIPPIAN SYSTEM.			
Gray shale	10	475	Waverly
Blue shale and lime	30	505	
Blue shale	20	525	
White lime (Big Lime)	75	600	
Green sand and shales	269	869	
Light gray sand (Wier)	46	915	
Black shale	34	949	

Driller, E. F. Henry.

NOTE:—Wier sand gas gauged over 2,000,000 cubic feet.

LOG No. 14.

Harris Howard No. 1, Bed Rock Oil Co., Lessee; Meadow Branch of Licking River, just above the forks of the Branch up the Right Fork.

Elevation Surface about 940 ft.

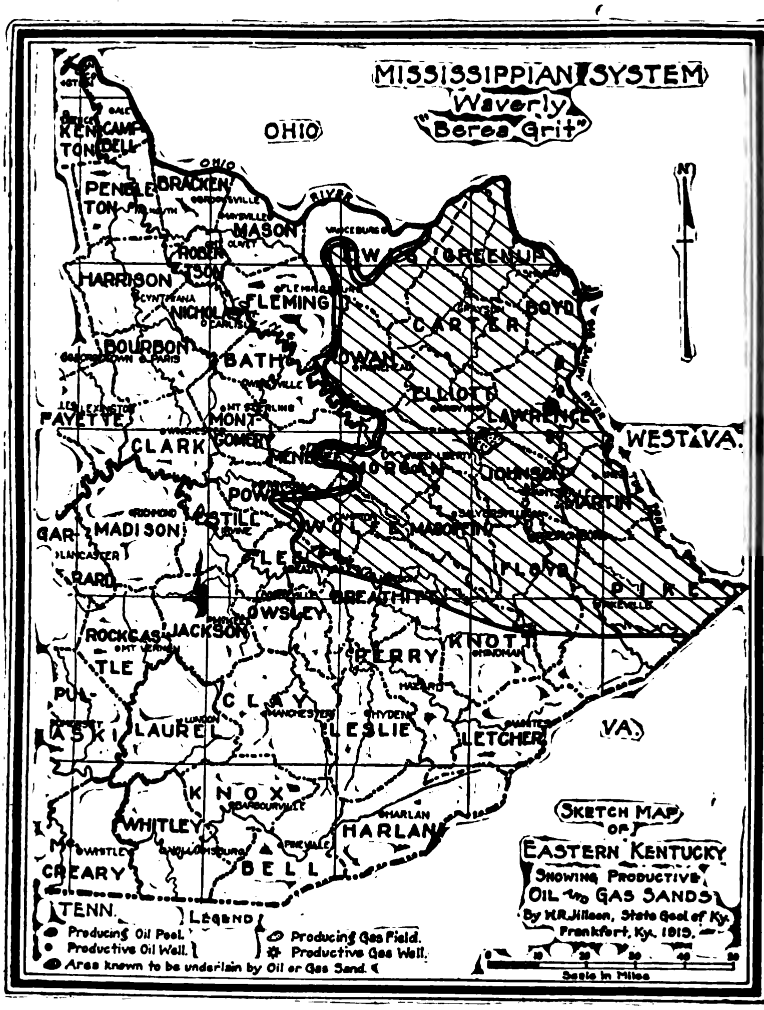
Strata	Thickness	Depth	
PENNSYLVANIAN SYSTEM.			
Drift	26	26	
Shale	34	60	
Coal	3	63	
Sand	104	167	
Coal	3	170	
Sand	5	185	
Sand—black oil	10	195	Pottsville

Sand	80	275	
Bluish shalé	25	300	
Sand	20	320	
Shales	155	475	
Sand with gas	25	500	
White sand—show of oil..	50	550	
Sand—salt water	20	570	
MISSISSIPPIAN SYSTEM.			
Shale	170	740	St. Genevieve-
White lime (Big Lime)	95	835	St. Louis
Shales	335	1160	Waverly
Sand (Wier)	90	1255	Waverly
Sandy lime	60	1310	Waverly
Black shale (Sunbury)	40	1350	Waverly
Yellow hard shale	40	1390	Waverly
DEVONIAN SYSTEM.			
Black shale	360	1750	
Gray shale	115	1865	
Gray lime	90	1955	

NOTE:—Salt water in Wier at 1170. The last gray lime 90 feet thick, may be the Onondaga. It produced 100,000 cu. ft. gas.

The lowermost and delimiting sand of the Waverly Group and the lowest formation in the Mississippian System in Kentucky is the Berea Grit, which underlies the northern part of Eastern Kentucky. Its southern extension is along a line similar to that shown on sketch map, Figure 6. The Berea, a representative producer of southeastern Ohio, has a considerable area of productivity in Eatern Kentucky. Due, however, to the fact that it pinches out to the south, the areas in which it will be found commercially important as an oil horizon have probably now been well ascertained and are in the counties of Lawrence, Elliott, Morgan and northern Magoffin, Johnson and Martin. Three logs are presented herewith to show the stratigraphic sequence and depth of this sand.

FIG. 6.


MISSISSIPPIAN SYSTEM
Waverly
"Berea Grit"
OHIO
OHIO RIVER
WEST VA.
VA.
TENN.
BRACKEN
MASON
HARRISON
FLEMING
NICHOLAS
BOURBON
BATH
FAYETTE
CLARK
MADISON
ESTILL
JACKSON
OWSLEY
BREATHITT
PERRY
KNOTT
CLAY
LESLIE
LETCHER
LAUREL
KNOX
WHITLEY
HARLAN
BELL
CARTER
BOYD
ELLIOTT
LAWRENCE
MORGAN
JOHNSON
MARTIN
FLOYD
PIKE
WOLFE
MAGOFFIN
SKETCH MAP OF EASTERN KENTUCKY SHOWING PRODUCTIVE OIL AND GAS SANDS
By W.R.Jillson, State Geol of Ky.
Frankfort, Ky. 1919.
LEGEND
Producing Oil Pool.
Productive Oil Well.
Producing Gas Field.
Productive Gas Well.
Area known to be underlain by Oil or Gas Sand.
Scale in Miles

LAWRENCE COUNTY

WELL RECORDS SHOWING "BEREA" SAND

LOG No. 15.

Strata	Thickness	Depth	
PENNSYLVANIAN SYSTEM.			
Gravel	39	39	
Lime	11	50	
Slate	80	130	
Sand	55	185	
Slate	225	410	
Sand	20	430	Pottsville
Slate	45	475	
Sand	160	635	
Slate	5	640	
Sand	230	870	
Slate (base of Pottsville)	10	880	
MISSISSIPPIAN SYSTEM.			
"Little lime"	20	900	
"Big lime"	150	1050	St. Genevieve-
Slate	10	1060	St. Louis
Shale	20	1080	
Sand	422	1502	
Black shale (Sunbury)	15	1517	
"Berea" sand—oil	15	1517	Waverly

BOYD COUNTY

LOG No. 16.

BIG SANDY OIL AND GAS CO. WELL.

Catletts Creek, 11½ Miles from Catlettsburg.

Strata	Thickness	Depth	
PENNSYLVANIAN SYSTEM.			
Clay and sand	36	36	
Sandstone	104	140	
Clay shale	100	240	Pottsville
Gray sand	30	270	
Shale	150	420	
Sand (base of Pottsville)	150	570	

MISSISSIPPIAN SYSTEM.			
Limestone—"Big Lime"....	**280**	**850**	**St. Genevieve-St. Louis**
Black sand	**100**	**950**	**Waverly**
White sand—Salt water....	**15**	**965**	
Black sand	**35**	**1000**	
Black shale—Oil show	**329**	**1329**	
Sand—Oil	**51**	**1380**	
Black slate (Sunbury shale)	**45**	**1425**	
Brown sand (Berea)	**15**	**1440**	
Shale and sand (Berea)	**5**	**1445**	
DEVONIAN SYSTEM.			
Black slate	**130**	**1575**	
White slate	**40**	**1615**	
SILURIAN SYSTEM.			
Slate and shale	**180**	**1795**	
Slate and shells	**50**	**1845**	**Niagaran**
Sand—Gas	**5**	**1850**	
Black slate	**10**	**1860**	
Black sand	**15**	**1875**	
Black sand and slate	**3**	**1878**	
Blue slate	**12**	**1890**	
Brown slate	**7**	**1897**	
Black slate	**68**	**1965**	
Black sand—Gas	**9**	**1974**	
Black shale	**52**	**2126**	

THE DEVONIAN SYSTEM

THE CHATTANOOGA SHALE

The most easily recognized, relatively deep petroliferous horizon in Eastern Kentucky is the Chattanooga Shale, correlative in part or in whole to the Genesee and Ohio Black Shale. It is commonly known in Kentucky simply as the "Black Shale." Its outcrop is found along a general northeast southwest line, slightly removed to the northwest of the border of the Eastern Coal field, and is indicated by a double line on the sketch map, figure 7. Though found at relatively shallow depth in the western part of the Eastern Coal field, the Black Shale, due to the normal dip of the subsurface strata of Eastern Kentucky, rapidly falls into deeper levels, with the result that the great number of shallow wells which have been drilled in southeastern Kentucky have never penetrated it. Its thickness varies from 20

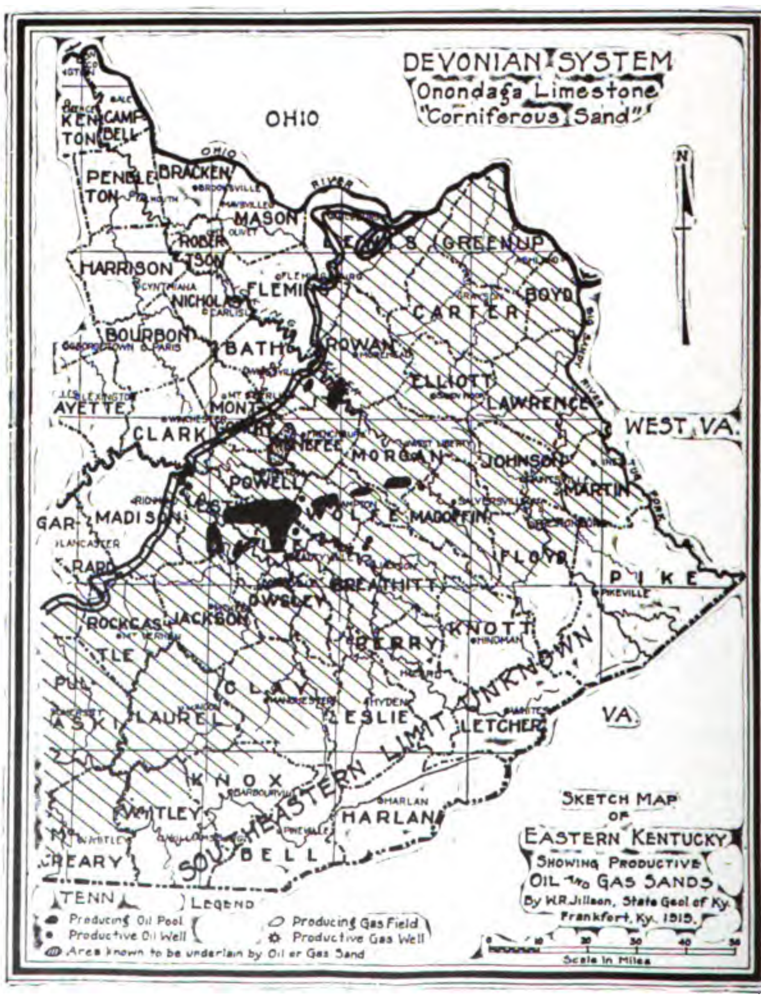
FIG. 7.

feet to 250 feet. Though highly petroliferous and always gassy in streaks, the Black Shale may not be considered as an important oil horizon in Kentucky. On the Aker Branch of Left Beaver Creek, in Floyd County, however, there is a gas well drilled into a sand inclusion of the Black Shale at a depth of 2,002 feet, which is very productive, and it is possible that other

wells drilled into this sand lens will also be productive of gas. Generally, however, drilling to the Black Shale for production of gas should be discouraged on the basis of the large number of unproductive wells drilled to and through this horizon.

Directly underlying the Black Shale and probably generally conformable to it is found the Onondaga Limestone. This is what is known among drillers as the Corniferous Lime or Sand

FIG. 8.



and is the same as the Ragland, Menifee, Irvine, Cannel City and Campton Sands. It is the most highly productive oil horizon in Eastern Kentucky and the state. The Ragland, Olympia, Irvine, Ashley, Big Sinking, Station Camp, Ross Creek, Campton, Stillwater, Cannel City and other associated and less important oil pools secure their production from this horizon. The gas of the Menifee Gas field also comes from the Onondaga Limestone. The subsurface extent of the Onondaga Limestone is shown on sketch map, Figure 8.

Due to its great depth in the southeastern extremity in Eastern Kentucky very little drilling has been extended to this horizon and for this reason its extent and characteristics in this section of the state are unknown. Within general limits, however, the Onondaga is a rather thin (25 to 45 feet) magnesian limestone, with many cherty inclusions. In the oil producing sections it is porous, due to either solution or dolomitization or both. The Onondaga Limestone is chiefly productive on anticlinal or doming structure, when such structure is accompanied by porous conditions. No production has ever been secured from the Onondaga in the Eastern Kentucky Geosyncline nor on its southeastern flank, and it is doubtful if any further extensions in this horizon will ever be made, except along the southeastern flank of the Cincinnati Arch. Several well logs given herewith illustrate the Onondaga in various sections of Eastern Kentucky.

THE SILURIAN SYSTEM

The Niagara Limestone and Shales

Beneath the Onondaga Limestone, and in many drill records distinguished from it with difficulty, are found a series of shaly limestones and green to pink shales, which belong to the Niagara group. The portion of the limestones directly underlying the Onondaga are frequently sandy and are possibly contributory to some of the production of the Estill-Lee-Powell-Wolfe Oil fields of Eastern Kentucky. The lower portion of the Silurian System contains the well known Clinton Sand, which is a limestone generally of reddish color and possesses the flaxseed lithological characteristic. This limestone, productive elsewhere, has

FIG. 9.

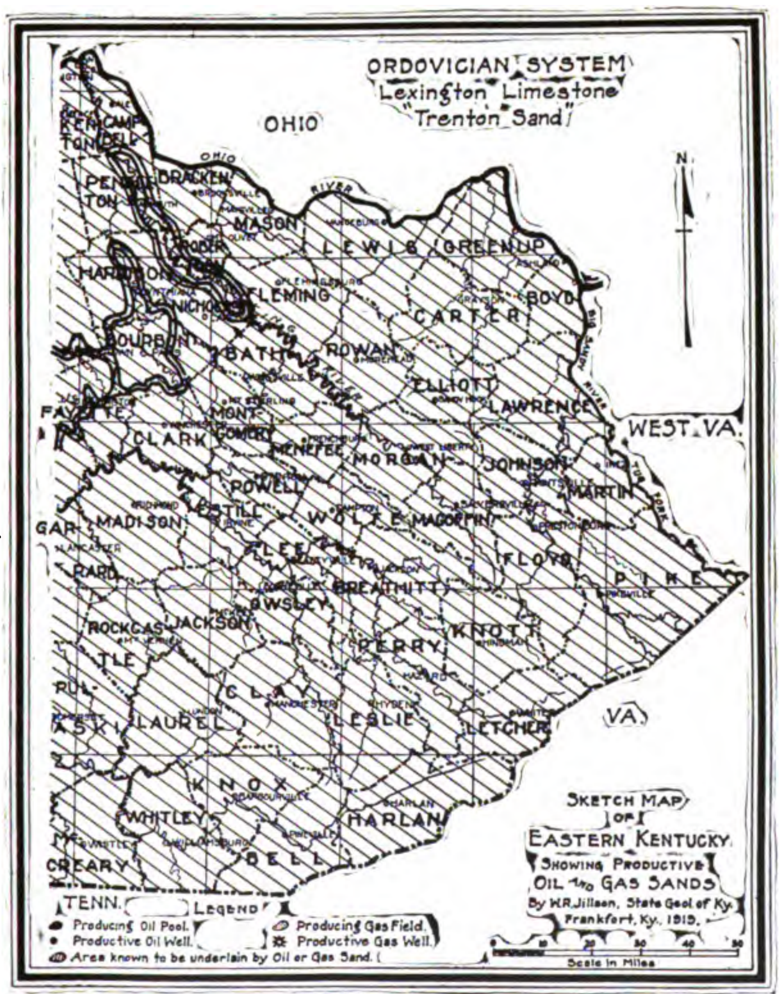
been the quest of much drilling in Eastern Kentucky, but has never been definitely shown to be of real commercial importance in this part of the state. The rocks of the Silurian System are penetrated by the drill frequently along the western border of the Eastern Coal field, but due to their depth are rarely touched in any other part of Eastern Kentucky and the horizon may not be considered in this part of the state as an important oil and gas producer.

THE ORDOVICIAN SYSTEM

The Lexington Limestone

Outcropping in the Central Blue Grass area of Kentucky and extending southeastward under cover and to considerable depth as the West Virginia, Virginia and Tennessee lines are approached, the Lexington Limestone, which contains the well-

FIG. 10.



known Trenton Sand, may be said to extend under all of Eastern Kentucky. A considerable number of widely separated deep wells have touched the Trenton horizon in this part of the state, but at no point has commercial oil or gas production been encountered. Its probable subsurface extent is given on sketch map, Figure 10, but fruther discussion with respect to its lithology, etc., is here omitted, due to the fact that it is considered unimportant from an oil and gas producing standpoint in this part of Kentucky.

As the work of prospecting for oil and gas in Eastern Kentucky continues it is only reasonable to believe that much that is now unknown respecting the extent and productivity of the sequence of oil and gas sands herein discussed, will be brought to light. This new information will undoubtedly cause various changes to be made in the subsurface extent of these sands as indicated on the accompanying maps. In making practical use of these maps it should be borne in mind that the area they cover is very large (about 18,000 square miles) and that the total of the included areas of known oil and gas geology is, in comparison, very small indeed.

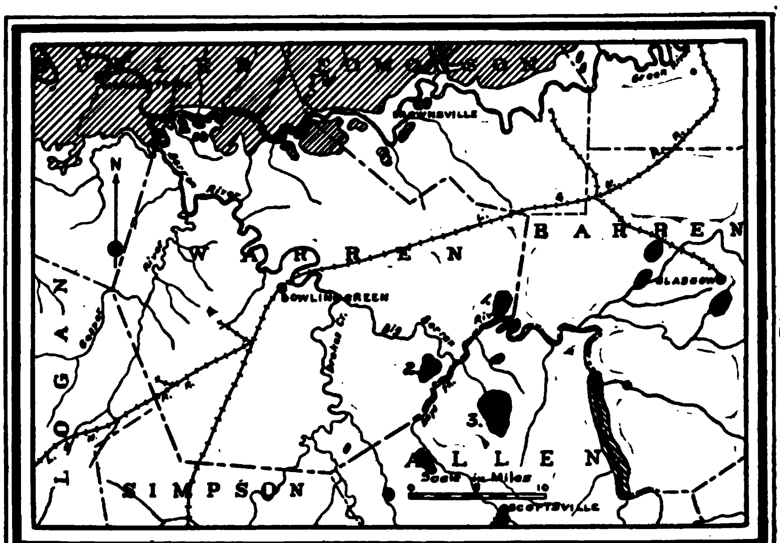
First Published October, 1919.

XIV.

THE NEW OIL AND GAS POOLS
of
WARREN COUNTY, KENTUCKY.

Location and Topography

Warren County is located in Southern Kentucky, in what is known as the "Pennyrile." Bowling Green, which is its county seat and largest town, is found in the central part of the county and is about ninety-five miles in an air line slightly to the southwest of Louisville, Kentucky, and twenty-five miles to the north of the Tennessee line. Warren county is bounded on the north and northwest by Butler; on the north and northeast by Edmonson; on the east by Barren; on the southeast by Allen;



SKETCH MAP OF WARREN AND ADJOINING COUNTIES

As shown above the principal Oil Pools of Warren County are: 1. The Moulder Pool; 2. The Green Hill Oil Pool. In Allen County there are a number of oil pools, the largest of which 3 is the Gainesville Pool. The hatchered areas in Warren County are Pennsylvanian, the light areas Mississippian.

on the south by Simpson, and on the southwest and west by Logan. Its area is about 563 square miles. The altitude of the surface of the county varies generally from 550 feet to 650 feet above sea level in the southeast, and from 450 feet to 750 feet above sea level in the northwestern portion of the county. The Barren River, which is the line of lowest drainage, enters the county from the east at an elevation of about 500 feet and leaves the county, joining the Green River, near the town of Woodbury to the northwest, at an elevation of 421 feet. Warren County, with the exception of small areas in the extreme northern portion, where the coal measures overlap, is essentially a very imperfectly dissected, gently northwestward undulating table land, in which the large streams have incised themselves, giving a rolling effect. The only rugged topography is found along the Barren and Green Rivers and along the lower courses of their larger tributaries. The relief varies generally from 50 to 350 feet. The improved pikes of the county are loocated on the round ridges to avoid, in so far as possible, the imperfect drainage of a very large number of sink holes, which are conspicuously distributed throughout the St. Louis Limestone belt in southeastern and central portion of the county. The principal lines of drainage are the Green and Barren Rivers and their tributaries.

ACKNOWLEDGMENTS

The material herewith presented represents a summation of such information as could be gathered from the publications of the former Geological Surveys of Kentucky, coupled with many personal notes collected by the writer while engaged in making many field examinations in Warren and adjacent counties during the years 1918 and 1919. During the year 1919 especially, Warren County has enjoyed the focussed attention of the oil prospecting public of this and adjoining states. The oil and gas development of this portion of Kentucky is now going forward so rapidly—twenty completions reported for the week ending November 1st—that it is almost impossible to present any report that is thoroughly up to date. It is the purpose of this publication, however, observing the limitations, to sketch in the main facts of the geology of the oil and gas of Warren county, leaving

the main amount of detail for a later and more comprehensive report. Thanks for many suggestions and much assistance in preparing this material are due to Mr. J. S. Kirby, Mr. C. A. Phelps and Mr. M. H. Crump, all of Bowling Green.

PUMP WELL COVINGTON NO. 1

The production is shallow, being from the Waverly. The lease is located on the outskirts of Bowling Green. Photo by W. R. Jillson. September, 1919.

Stratigraphic Geology

The principal surficial rocks of Warren County belong to the Mississippian and Pennsylvanian Systems (see large sketch map). The Mississippian Rocks are chiefly limestone, the Gasper and St. Genevieve Oolites, the St. Louis and the Warsaw forming the principal exposures. At the top of the Mississippian System is found the Cypress Sandstone. The Pennsylvanian Rocks, clastics, are principally conglomerate sandstones, shales, and coals of the Pottsville. The Pennsylvanian exposures overlap a small area in the northern part of the county, the Mississippian, Cypress, Gasper, St. Genevieve, St. Louis and Warsaw formations covering in the same order the remaining and principal area as one progresses to the southeast.

SHOOTING THE HUNTER NO. 1

This well is located about two miles west of Bowling Green, on the Morgantown Pike. It produced both oil and gas. Photo by W. R. Jillson. September, 1919.

The subsurface stratigraphy is composed of the Fort Payne formation, essentially a chirty limestone, which is the basal member of the Mississippian. Underlying this formation is found the uppermost division of the Devonian, which is the Black or Chattanooga Shale. This shale is underlain by the Hamilton and Onondaga Limestone of the Devonian; the Niagarian Limestone of the Silurian and the Trenton Limestone of the Ordovician. In descending order the productive "sands" are lenses in the Warsaw-Fort Payne, of the Mississippian; porous horizons in the Hamilton or Onondaga (Corniferous) of the Devonian, and sandy horizons in the Niagarian, and Trenton groups of the Silurian and Ordivician, respectively. A generalized section of the exposed and unexposed rocks and oil sands of Warren county is as follows:

MIDDLE PALEOZOIC SERIES IN WARREN COUNTY AND CORRESPONDING OIL SANDS

System	Series	Producing Sands	Notes	Lithology
Pennsylvanian	Pottsville	None	Exposed—Not productive	Sandstone, shale, coals
	Chester	Big Lime	Exposed—Not a producer	Limestones
Mississippian	Waverly	Fort Payne or Beaver Sand	Exposed partly Possible producer	Limestone
	Chattanooga	Stray Sands	Occasionally gas	Black Shale
Devonian	Hamilton Onondaga	Moulder Gainesville Rodemer Boyds Creek Scottsville	The principal oil and gas producing horizons in Allen county and vicinity.	Cavernous Limestone
	Niagara			Sandy, impure Limestones
Silurian	Clinton	Deep Sands	Very occasional producer	Limestones and shales
Ordovician	Cincinnatian	Upper Sunnybrook Deep Sand	Very occasional producer	Mostly Limestones
	Mohawkian	Trenton Deep Sands	Very occasional producer	Mostly Limestones

The Producing Oil Sands.

While there are certainly four horizons, the Warsaw-Fort Payne, in the lower Mississippian; the Hamilton-Onondaga (Corniferous), in the Devonian, the Niagaran of the Silurian; and the Trenton of the Ordovician, this number of sands may for all practicable purposes be reduced to one, the Onondaga

SHOOTING THE SIMPSON NO. 1
Photo by W. R. Jillson. September, 1919.

(Corniferous), directly underlying the Black Shale, which is the principal oil horizon. At least ninety-five per cent of the wells designated as producers find some if not their principal production in this horizon, though there are a large number of wells, especially in central Warren County, which have obtained small high grade production from the "sands" of the Warsaw and Fort Payne. The production secured from this latter group of Mississippian Rocks is generally very light in gravity and in thin

films frequently shows an amber color, from which fact it has taken the name, "Amber Oil." The production secured below the Black Shale in the Onondaga (Corniferous) limestone is green crude, with a gravity ranging from 30 to 38 Baume'. Herewith are included five analyses of crude oil taken by the writer from various localities in Warren County.

ANALYSES OF WARREN COUNTY OIL

ANALYSIS NO. 1.

LABORATORY No. G-3864—Petroleum, labeled "(d) Green oil—Maj. R. W. Covington, No. 1, 355 feet, above shale, 1-2 mile southeast of Bowling Green, Warren Co., Ky., Sept. 15, 1919. Collected by W. R. Jillson, Sept. 14, 1919."

Received from W. R. Jillson, State Geologist, September 15, 1919.

ANALYSIS

Specific gravity at 60° F., 0.854, equivalent to 33.9° B.

Distilled below 150° C. (302° F.)	13.0%	(Gasoline fraction)
Distilled from 150 to 300° C. (302-572° F.)	36.5%	(Burning oil fract.)
Tarry residue	50.0%	
Loss in analysis	0.5%	
	100.0%	

The oil began to distill at 75° C. (167° F.)

ALFRED M. PETER, Chief Chemist.

(Analysis by A. M. Peter)
Lexington, Ky., September 19, 1919.

ANALYSIS NO. 2.

LABORATORY No. G-3861—Petroleum labeled "(a) Lessor (Dr.) Hunter. Lessee, Duplex Oil Co., 3 miles west of Bowling Green, Warren County, Ky. 960 feet below shale."

Received from W. R. Jillson, State Geologist, September 15, 1919.

ANALYSIS

Specific gravity 0.834° at 60° F., equivalent to 37.9° B.

Distilled below 150° C. (302° F.)	20.2%	(Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	32.0%	(Burning oil fraction)
Thick, brown tar	45.0%	
Loss in analysis	2.8%	
	100.00%	

The oil began to distill at 65° C. (149° F.)

ALFRED M. PETER, Chief Chemist.

(Analysis by A. M. Peter)
Lexington, Ky., September 19, 1919.

Analysis No. 3

Laboratory No. G-3862—Petroleum labeled "(b) Green oil from J. A. Hamel & Co., Wayne O'Neil, lessee 1-2 mile northeast of Bowling Green, Warren County, Ky. Oil horizon, Onondaga and Niagara limestones. Depth 850 feet. Collected by W. R. Jillson, September 14, 1919."

Received from W. R. Jillson, State Geologist, September 15, 1919.

ANALYSIS

Specific gravity at 60° F., 0.856, equivalent to 33.6° B.

Distilled below 150° C. (302° F.)	14.5%	(Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	34.5%	(Burning oil fraction)
Tarry residue	50.5%	
Loss in analysis	.5%	

The oil began to distill at 65° C. (149° F.)

ALFRED M. PETER, Chief Chemist

(Analysis by A. M. Peter)
Lexington, Ky., September 19, 1919.

Analysis No. 4

Laboratory No. G-3863—Petroleum labeled "Green oil. open steel tank. Horace Bohon No. 1. A. Goldstine, lessee. 840

SHOOTING THE HAMILTON NO. 1

Photo by W. R. Jillson. September, 1919.

feet below shale. 1 mile east of Bowling Green, Warren County, Ky. Collected by W. R. Jillson, September 14, 1919."

Received from W. R. Jillson, State Geologist, September 15, 1919.

ANALYSIS

Specific gravity 60° F., 0.856, equivalent to 33.6° B.		
Distilled below 150° C. (302° F.)............	13.0%	(Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	36.5%	(Burning oil fraction)
Tarry residue and loss, by difference....	50.5%	
	100.0%	

The oil began to distill at 70° C. (158° F.)

ALFRED M. PTETR, Chief Chemist.

(Analysis by A. M. Peter)

Lexington, Ky., September 19, 1919.

Analysis No. 5

Laboratory No. G-3865—Petroleum, labeled "Fresh, green oil, Joe B. Sumpter, No 1, Mrs. Gray, lessee, 1-2 mile west of Bowling Green, Warren County, Ky. Oil at 880-900 feet, total depth 920 feet. Oil horizon, Niagara. Collected by W. R. Jillson, Sept. 14, 1919."

Received from W. R. Jillson, State Geologist, September 15, 1919.

ANALYSIS

Specific gravity at 60° F., 0.865, equivalent to 31.9° B.

Distilled below 150° C. (302° F.)	9.3%	(Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	37.5%	(Burning oil fraction)
Tarry residue	52.5%	
Loss in analysis	0.7%	
	100.0%	

The oil began to distill about 80° C. (176° F.)

ALFRED M. PETER, Chief Chemist.

(Analysis by A. M. Peter)
Lexington, Ky., September 19, 1919.

Analysis No. 7

Laboratory No. G-3879—Petroleum, labeled "Fresh natural flow of amber crude oil from the Jim Britt farm—Waverly sand—Warren County, Ky. Collected by W. R. Jillson, State Geologist, November 9, 1919." Sample, a thin, amber colored oil having a strong green fluorescence. When the bottle was uncorked a few small gas bubbles appeared in the liquid (temperature about 80° F.).

Specific gravity, 0.810, equivalent to 44.8° B.

Distillate below 150° C. (302° F.)	25.0%	(Gasoline fraction)
Distillate from 150° to 300° C. (302-572° F.)	38.8%	(Burning oil fraction)
Pasty, green residue	34.4%	
Loss in analysis	1.8%	
	100.0%	

Began to distill at 40° C. (148° F.)

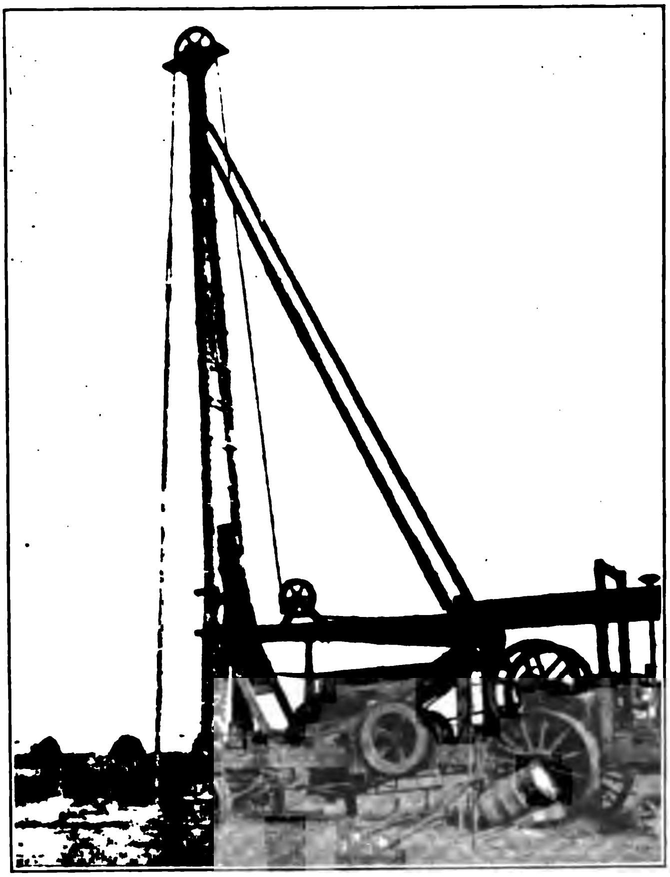
The residue after distillation still retained the strong, green florescence of the original oil. It partly solidied on cooling, apparently from the separation of solid paraffin.

ALFRED M. PETER, Chief Chemist.

(Analysis by A. M. Peter)
Lexington, Kentucky, November 13, 1919.

ANALYSIS NO. 8

LABORATORY NO. G-3880—Petroleum labeled "Fresh pumping olive-green crude oil from Sam Thomas heirs' lease, Waverly



THE BOWLING GREEN FAIR GROUNDS DRILLING

The location is in the southeastern limits of the city, between the Covington and Bohon properties. Photo by W. R Jillson. September, 1919.

sand, Warren County, Ky. Collected by W. R. Jillson, State Geologist, November 9, 1919." Sample a thin, green oil, dark brown by transmitted light.

Specific gravity, 0.844, equivalent to 35.9° B.

Distillate below 150° C. (302° F.)	20.0%	(Gasoline fraction)
Distillate from 150° to 300° C. (302-572° F.)	33.8%	(Burning oil fraction)
Thick, brown, oily residue	46.2%	
	100.0%	

Began to distill at 68° C. (199° F.)

ALFRED M. PETER, Chief Chemist.

(Analysis by A. M. Peter)
Lexington, Ky., November 13, 1919.

Analysis No. 9

Laboratory No. G-3881—Petroleum labeled "Fresh natural flowing crude green oil from Albert Covington lease, Warren County, Ky. Waverly sand producing. Collected by W. R. Jillson, State Geologist, Nov. 11, 1919." Sample a pint of thin, green oil, received November 24, 1919.

Specific gravity 0.8815, equivalent to 34.4° B.

Distilled below 150° C. (302° F.)	14.5%	(Gasoline fraction)
Distilled between 150° and 300° C. (302-572° F.)	38.5%	(Burning oil fraction)
Green and brown, thick residue	46.5%	
Loss in analysis	.5%	
	100.0%	

Began to distill at 70° (158° F.)

ALFRED M. PETER, Chief Chemist.

Lexington, Kentucky, November 26, 1919.

Analysis No. 10

Laboratory No. G-3888.—Petroleum labeled "Green crude oil, Glen Lily Tract, C. L. Goodrum lease, 1 mile west of Bowling Green, Warren County, Ky. Collected by C. H. Scott, Jan.

1, 1920." Sample, thin, green oil, dark brown by transmitted light. Forwarded by W. R. Jillson, State Geologist, for analysis.

Specific gravity, 0.848, equivalent to 35.1° B.

Distilled below 150° C. (302° F.)	21.5%	(Gasoline fraction)
Distilled 150° to 300° C. (302-572° F.)	33.8%	(Burning oil fraction)
Thick green-brown tar	44.4%	
Loss in analysis	.3%	
	100.0%	

Began to distill at 55° C. (131° F.)

ALFRED M. PETER, Chief Chemist.

(Analysis by A. M. Peter.)
Lexington, Ky., Feb. 6, 1920.

PRODUCTION OF CRUDE OIL

MOULDER OIL POOL

Pipeline Runs, Swiss Pipeline Company

August,* 1919	10,672.41 Barrels
September, 1919	6,217.09 Barrels
October, 1919	3,306.90 Barrels
November, 1919	3,210.70 Barrels
December, 1919	2,327.59 Barrels
	25,734.69 Barrels

*No oil was run previous to August, 1919.

WELL RECORDS

The subsurface stratigraphy and depths to the various oil horizons are perhaps best understood through a study of the logs of wells drilled in various localities. To facilitate such investigations as the reader may wish to make, there are presented herewith records, which are considered representative of Warren county. These wells are presented by pools and unaltered from the original figure, which is given in feet.

LOG No. 1. MOULDER OIL POOL

Moulder No. 2.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Limestone	260	260
DEVONIAN SYSTEM.		
Black shale	50	310
"Sand"	18	328
Limestone	180	508

Dry

LOG. No. 2.

Moulder No. 4.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Limestone	261	261
DEVONIAN SYSTEM.		
Black shale	45	306
"Sand"	15	321

Oil Flowing

LOG No. 3.

April 26, 1919.

B. G. Goodnight No. 1.

(Opposite Moulder)

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Limestone	295	295
DEVONIAN SYSTEM.		
Black shale	52	347
"Sand" (dry)	18	365
Limestone	37	402
"Sand"	13	415

Oil Show

LOG No. 4.

Moulder No. 3.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Limestone	242	242
DEVONIAN SYSTEM.		
Black shale	50	292
"Sand"	13	305

Oil Flowing

LOG No. 5.

April 26, 1919.

Moulder No. 5.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Limestone	252	252
DEVONIAN SYSTEM.		
Black shale	50	302
"Sand"	18	320

Oil Show

LOG No. 6.

Salt Water
Jewell No. 1.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Limestone	225	225
DEVONIAN SYSTEM.		
Black shale	50	275
"Sand"	15	290

Oil

LOG No. 7.

R. B. Osborn No. 1.
(2,000 ft. west of Jewell)

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Limestone	237	237
Black shale	42	279
"Sand"	11	290
Limestone	58	338

Salt Water

GREEN HILL OIL POOL
Authority, W. H. HOGE

LOG No. 8.

Moody No. 1.

	Feet
Top of shale	366
Bottom of shale	416
Bottom of cap rock	426
Bottom of first sand	433
Soft blue lime	
Top second sand	451
Bottom second sand	472

7 or 8 hundred thousand feet gas in Green Shale.

LOG No. 9.

Moody No. 2.

Top of shale	364
Bottom of shale	417
Bottom of cap rock	428
Bottom of first sand	439
Gray limestone	
Top of second sand	450
Bottom of second sand	470
Blue lime to	480%

Considerable Gas.

LOG No. 10. **Moody No. 3.**

Strata	Feet
Top of shale	361
Bottom of shale	414
Bottom of cap rock	424
Bottom of first sand	428
Soft blue lime	
Top of second sand	441
Bottom of second sand	461
Blue lime	
Top of third sand	511
Bottom of third sand	519
Top of fourth sand	558
Bottom of fourth sand	562
Total depth well	579
Small amount of gas.	

LOG No. 11. **Motley No. 1.**

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	19
Water	70
Sulphur	115
Cased	143
Green shale	250
DEVONIAN SYSTEM.	
Black shale	305
Cap rock	358
Sand	370
Brake	390
Sand	420
Brake	430
Sand	510
Whole	520

LOG No. 12. **Motley No. 2.**

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	18
Water	65
Sulphur	108
Cased	120
Green shale	240
DEVONIAN SYSTEM.	
Black shale	286
Cap rock	338
Pay	350
Whole	351

LOG No. 13.

Motley No. 3.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	19
Water	64
Sulphur	106
Cased	120
Green shale	240
DEVONIAN SYSTEM.	
Black shale	285
Cap rock	337
Pay	350
Whole	350

LOG No. 14.

Motley No. 4.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	19
Water	70
Sulphur	115
Casing	143
Green shale	255
DEVONIAN SYSTEM.	
Black shale	310
Cap rock	369
Sand	380
Brake	395
Whole (Dry)	433

LOG No. 15.

Motley Not 5.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	18
Water	68
Sulphur	104
Cased	110
Green shale	260
DEVONIAN SYSTEM.	
Black shale	313
Cap rock	370
Pay	382
Whole	382

LOG No. 16.

Motley No. 6.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	14
Water	60
Sulphur	100
Cased	110
Green shale	252
DEVONIAN SYSTEM.	
Black shale	302
Cap rock	353
Brake	360
Sand	370
Brake	383
Whole	383

LOG No. 17.

Finney No. 1.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	3
Water	40
Sulphur	70
Casing	140
Green shale	190
DEVONIAN SYSTEM.	
Black shale	214
Cap rock	275
Brake	281
Pay	287
Whole	300

LOG No. 18.

Finney No. 3.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Earth	19
Water (no)	.....
Sulphur	100
Casing	120

LOG No. 19.

Finney No. 5.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	20
Water	40
Sulphur	80
Casing	110
Green shale	185
DEVONIAN SYSTEM.	
Black shale	210
Cap rock	260
Brake	272
Sand	284
Brake	......
Sand	......

LOG No. 20.

Finney No. 2.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	9
Water	30
Sulphur	90
Casing	120
Green shale	225
DEVONIAN SYSTEM.	
Black shale	255
Cap rock	355
Pay	370
Whole	374

LOG No. 21.

Finney No. 4.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Earth	18
Water	36
Sulphur	94
Casing	100
Green shale	225
DEVONIAN SYSTEM.	
Black shale	250
Cap rock	352

LOG No. 22.

Finney No. 6.

Strata	Feet
MISSISSIPPIAN SYSTEM.	
Soil	18
Water	38
Sulphur	75
Casing	105
Green shale	180
DEVONIAN SYSTEM.	
Black shale	212
Cap rock	258
Brake	270
Sand	321
(Whole)	342

VARIOUS LOCATIONS IN WARREN COUNTY

LOG No. 23.

Hamilton No. 1.
(Just East of Bowling Green)

Strata	Thickness	Depth	
MISSISSIPPIAN SYSTEM.			
Lime and shale	598	598	
DEVONIAN SYSTEM.			
Black shale	77	675	
White lime	33	706	
Top of sand	18	726	Pay sand
Bottom of sand	23	749	Gray lime
Top of sand	11	760	Pay and Oil
SILURIAN SYSTEM.			
Blue lime	24	784	
Sand	8	792	Oil
Slate and shale	12	804	
Sand	8	812	Oil
Gray lime	18	830	Bottom

Authority of C. A. Phelps.

LOG No. 24.

WELL AT BOWLING GREEN.
(From drillings.)

MISSISSIPPIAN SYSTEM.

White oolite.	
Gray lime	at 18, 25 and 30
Light gray oolite	at 36
Fine-grained white lime	at 42 and 46 to 70
Light gray lime	at 77, 90, 94 and 98
White lime	at 100

Light brown lime ....at 106
Light gray lime ....at 112, 117, 130, 135, 144 and 156 to 170
Dark gray lime ....at 183
Gray lime shale ....at 189
Dark gray lime ....at 195, 205 and 210 to 230
Black lime ....at 235
Dark gray lime ....at 240
Light brown lime ....at 253
Gray lime ....at 255 and 260
Dark lime ....at 265
Brown lime ....at 270
Dark gray lime ....at 278 and 284
Brown lime ....at 287
Gray lime ....at 288, 290, 294, 300, 305, 310 and 315
Very dark lime ....at 325 and 330
Gray lime—oil at 363 ....at 340, 348, 350 and 358 to 380
Gray lime shale ....at 400 to 420
Gray lime ....at 425 and 430
Gray lime and shale ....at 435, 440, 445 and 450
Gray and white limes ....at 455
Gray lime and shale ....at 460 and 465
Gray and white lime ....at 470
Gray lime ....at 475
Gray lime and white shale ....at 485
Dark limy shale ....at 490 to 501
Gray lime and limy shales .... 506, 510 and 515
Gray limy shale ....at 520 to 530
Dark lime and limy shales ....at 535 to 665
Black slate ....at 670 to 680
Very dark limy shale ....at 685
Brown impure lime ....at 690
Dark impure lime ....at 695 and 700
Gray and white lime ....at 705

DEVONIAN SYSTEM

Black shale ....at 708 to 760
Dark brown sandy lime ....at 765 and 770
Mixed black, white and gray limes ....at 775
Fine-grained white lime ....at 780

SILURIAN SYSTEM.

Fine-grained yellowish lime ....at 785 and 790
Fine-grained white lime ....at 795 to 875
Gray lime ....at 880 to 890
Very light lime ....at 895 and 900
Gray lime ....at 910
Light lime ....at 915 to 935
Mottled red lime ....at 940

ORDOVICIAN SYSTEM.

Gray lime	at 945 and 950
Light and gray limes	at 955, 960, 965, 975 and 980
Gray lime and shale	at 985
Mottled gray and white lime	at 990
Gray lime	at 995 to 1010 and 1015
Light lime	at 1020 and 1025
Gray lime and shale	at 1030 to 1095
Light and gray limes	at 1100 to 1185
White lime	at 1190
Gray limes	at 1195 to 1420
Dark limy shale	at 1425
Gray lime	at 1430 to 1440
Black and white limes	at 1445
Gray lime	at 1450 to 1460
Brown lime	at 1465
Gray lime	at 1470 to 1595
Light lime	at 1600 to 1605
Dark and light limes	at 1610 to 1660
Light dove-colored lime (top of Tyrone)	at 1660 to 1670
Gray and light limes	at 1685 to 1715
Very dark lime	at 1720 to 1730
Black lime	at 1735
Dark brown lime	at 1740 and 1745
Black lime	at 1750
Dark brown lime	at 1755
Gray lime	at 1760 and 1765
Very dark lime	at 1770
Gray lime	at 1775
Very dark lime	at 1780

LOG No. 25.

STAHL FARM.

West of Bowling Green.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Soil	4	4
White lime	211	215
Brown lime—black sulphur water at 295	85	300
White lime	150	450
Brown lime—"Blue Lick" water at 560	110	560
Lime	40	600
Blue shale	5	605
Hard lime	10	615
White lime	85	700
White shale	1	701

Brown lime	149	850
White lime	60	910
Blue lime	35	945
DEVONIAN SYSTEM.		
Black shale	110	1055
Brown lime	10	1065
SILURIAN SYSTEM.		
White lime	5	1070
Blue lime	25	1095
Cream-colored lime—oil	10	1105
Brown lime	6	1111
Cream-colored lime—oil	10	1121
Broken lime	19	1140
Very fine sand (lime?)	3	1143

LOG No. 26.

A. M. KIRBY WELL.

East of Alvaton.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Blue limestone	6	6
Flint	24	30
Gray limestone	15	45
Blue limestone	63	108
Yellow shale	8	116
Blue limestone	4	120
Gray limestone	30	150
Blue limestone	25	175
Gray limestone	49	224
Brown limestone	41	265
Lighter limestone	20	285
White limestone	35	320
Light gray limestone	15	335
White limestone	10	345
Blue limestone	35	400
DEVONIAN SYSTEM.		
Black shale	40	440
Blue lime	63	503
Lime sand	12	515
Blue limestone	10	525
Lime sand	15	540
Blue limestone	10	550
Lime sand	20	570
Blue limestone	15	580

Gas well.

LOG No. 27.

LARMON WELL No. 1.
West of Alvation

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Clay	25	25
Limestone	30	55
Lime shells	20	75
Slate	5	80
Soapstone	3	83
Limestone	20	103
Limestone	7	110
Sandy lime	5	115
Limestone	45	160
Lime shells	40	200
Sand shells	15	215
Brown lime	28	243
Sandy lime	12	255
Limestone	4	259
Shale	10	269
Limestone	14	283
Shale, sandy	45	328
Limestone	6	334
Shale, sandy	11	345
Limestone	11	356
Slate pencil	19	375
Lime, shelly	23	398
Slate	7	405
Sand shells	15	420
Slate	4	425
Limestone	45	470
Lime shells	5	475
Slate and shells	70	545
Limestone	12	557
Shale	6	563
Lime shell	1	564
DEVONIAN SYSTEM.		
Shale	20	584
Shale	29	612
Limestone	4	616
Lime, sandy	20	636
Limestone	14	650
SILURIAN SYSTEM.		
Limestone, sandy	5	655
Limestone	5	660
Limestone, sandy	5	665
Soapstone and sand	14	679

Limestone	4	683
Limestone	5	688
Limestone	4	692
Shale, sandy	32	724

LOG No. 28.

GARRISON FARM.
East of Bowling Green.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Soil	27	27
Lime	105	132
"Gas sand"	5	137
Lime	63	200
"Gas sand"	10	210
Lime	135	345
Green slate	37	382
Broken lime	8	390
DEVONIAN SYSTEM.		
Black shale	60	450
Brown lime	4	454
White lime	8	462
Brown lime—gas	28	490
SILURIAN SYSTEM.		
White lime	8	498
Brown lime	12	510
Gray lime	15	525
Brown lime—oil	12	537
Gray lime	45	582
Brown lime	8	590
Gray lime	10	600

LOG No. 29.

B. F. AMOS FARM.
Near Oakland.

Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
Red clay	14	14
Lime	156	170
Sand	25	195
Lime	76	271
Slate	6	277
Lime	233	510
Slate	12	522
Lime	118	640

DEVONIAN SYSTEM.		
Brown shale	82	722
Lime	102	824
Sand—gas	24	848
Lime	177	1025
Red rock	44	1069
ORDOVICIAN SYSTEM.		
Lime	273	1342
Slate	116	1458
Lime	19	1477
Slate	6	1483
Lime	67	1550
Trenton*	59	1609

*Driller's distinction.

Top of Silurian passed by driller in 102 feet of lime below 722 feet.

LOG No. 30.

LUTHER JACKSON FARM.

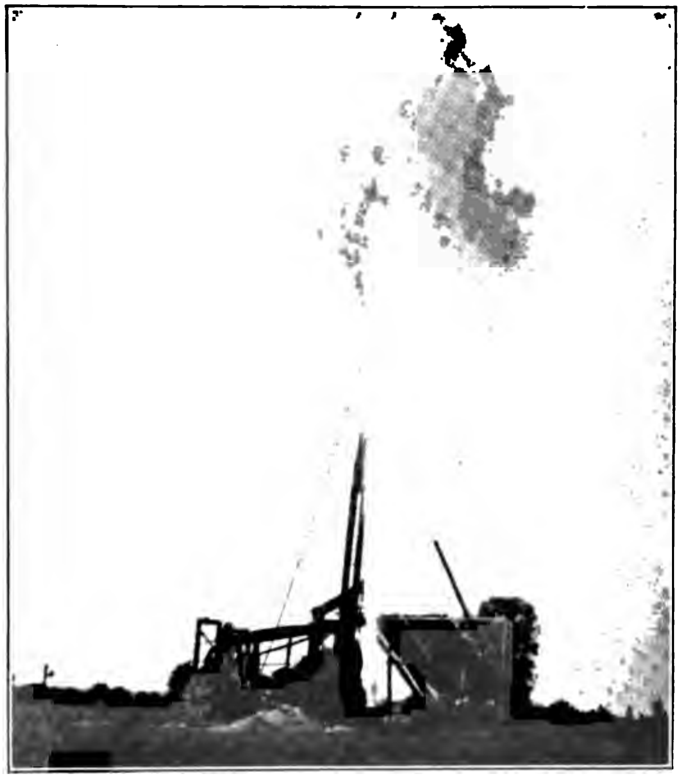
Strata	Thickness	Depth
MISSISSIPPIAN SYSTEM.		
White lime	35	35
Gray lime	105	140
White lime	120	260
Gray lime	315	575
Blue lime	90	665
Gray lime	30	695
Blue lime	315	1010
DEVONIAN SYSTEM.		
Black shale	102	1112
Gray lime—oil show	56	1168
SILURIAN SYSTEM.		
Light brown lime	10	1178
Gray lime	15	1193
Brown lime	8	1201
Light gray lime—oil show	7	1208
White lime	6	1214
Light gray lime	25	1239
White lime	5	1244
Light gray lime	28	1272
Gray lime	30	1302
Brown lime	33	1335
Gray lime with blue shale streaks	240	1575
Red rock	10	1585

ORDOVICIAN SYSTEM.

Soft broken lime	305	1890
Hard blue lime	98	1988
Brown sand	4	1992
Hard brown lime	5	1997
Dark blue shale	10	2007
Blue lime	31	2038

STRUCTURAL GEOLOGY

The general structure of Warren County is simple. The normal stratigraphical dip is to the northwest, the fall amounting to between thirty and thirty-five feet to the mile. This normal dip is broken by a series of flexures or folds, which sometimes show a reversal and closed contour, and at other times simply a flattening to a definite terrace. The axes of these struc-



SHOOTING THE BOHON NO. 1
Photo by W. R. Jillson. August, 1919.

tures are generally northeast and southwest. For the most part the minor axis is short, giving a figure something in the shape of an overturned canoe. The number of closed or domed structures is relatively small. Due to the thick manteling of the red residual limestone soil which covers the principal part of the county, very few of the structures which must exist in Warren County can be seen at the surface. The widely distributed number of structures which have been found and mapped, however, stands as a strong indication of the fact that many others do exist and will be found later, in some cases by the drill. A number of the structures of Warren County have been plotted on the development map accompanying this report.

Oil and Gas Development

The principal area of development in Warren County to date, and the best in so far as development has produced the proof of production, lies in a belt running from the northeast to the southwest along the eastern boundary of the county. The belt includes the well known Moulder and Green Hill Oil Pools. It is an area pregnant with many possibilities, for some of the largest flush production which has ever been secured in Kentucky came during the present year from the Moulder Pool. The depths along this belt vary from 400 to 550 feet to the Onondaga (Corniferous) Limestone, which is the productive horizon. Altogether about three hundred wells have been drilled in this section and the larger number of these have shown production of commercial importance. West of the Green Hill Oil Pool along Drakes Creek a number of gas wells were drilled in some years ago, but are not of particular importance. In and about Bowling Green a number of wells have been drilled, most of which have secured oil from the Warsaw-Fort Payne horizons, of the Mississippian. A few have brought in production from the Onondaga (Corniferous). of the Devonian. Due west of Bowling Green adjoining the Morgatown Pike and Gaspers River, there is some old development and production in what is known as the Jackson Pool. Northwest of Bowling Green on the Rayes Valley Pike, near Richardsville. a number of wells have been drilled to the Onondaga (Corniferous), with varying results. Some production and some salt water has been secured. West and northwest

of Bowling Green, about four miles, several wells have been drilled in recently to oil and gas production in the Onondaga (Corniferous) Limestone, which suggests productive possibilities for this section. Of chief present interest in this section are the new and promising Hunter and Davenport wells. Very little development has gone forward in northern Warren County in the Sand Hill and Plum Spring sections, or in southwestern Warren County, near Rockfield and Woodburn. The most promising area in Warren County for development purposes is the belt along the Allen-Barren line, where the Green Hill and Moulder Pools have been developed. To the practical man this area is important, because of the shallow drilling depths and a generally porous condition found in the Onondaga (Corniferous) Limestone. In comparison to this area the remainder of Warren County, excepting the district about Thomas' Landing, is at present much less attractive, though not without immense possibilities. A large number of scattered wells, however, show the sands under the western area to be not only deep, but tight, two considerations which militate against successful drilling.

Established and Operating Pipe Lines

The Green Hill Pool is served by the Bowling Green Pipe Line, four inches, replacing the old two inch line of the American Pipe Line Company. The Moulder Pool is served by the Swiss Pipe Line, four inches, and by the Butler Pipe Line, four inches, both of which find their terminus and loading rack at Smiths Grove.

First Published October, 1919.

XV.

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First Published April, 1919.

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